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APPLICATION OF REINFORCED FIBERGLASS TO THE HOOD/FENDER ASSEMBLY FOR THE M939 5-TON TRUCK

U.S. ARMY TACOM

MAY 82

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An effort to apply fiberglass reinforced plastic (E-glass/epoxy) to the construction of an M939/M963 hood/fender assembly was undertaken. Material characterization and the finite element analysis were completed.

Soft tooling for both hoods was made and pre-production prototypes of the M939 hood/fender assembly were made. The feasibility of manufacture was proved.

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1. SUMMARY

An effort to apply fiberglass reinforced plastic (E-glass-epoxy) to the construction of an M939/M963 hood/fender assembly was undertaken. Material characterization and the finite element analysis were completed.

Soft tooling for both hoods was made and pre-production prototypes of the M939 hood/fender assembly were made. The feasibility of manufacture was proved.

2. PREFACE

A contract was awarded to Ewald Associates, Inc., Detroit, MI, to design the hood/fender assembly from fiberglass-reinforced plastic. The original hood/fender assembly selected was that of the XM963 2-1/2-ton truck. Midway through the project, the hood/fender assembly to be used was changed to the M939 5-ton truck. In February 1980, orders were received to terminate the project; thus, the contract was terminated for the convenience of the Government. On both vehicles, soft tooling was completed and drawings were made. Material characterization and finite element were completed. This report discusses the finite element analysis of the structures and the material characterization studies and also the tooling development. It should be pointed out that two complete hood/fender assemblies of the M939 5-ton truck configuration were molded of fiberglass-bonded with a resin which would not perform at the high temperature specified for vehicle operation.

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3. INTRODUCTION

The automotive industry, pushed by the requirment for improved fuel economy, is exploring any avenue which can reduce their product's appetite for fuel. Their search has led them to evaluate many materials which can reduce weight. One of the materials proven to be satisfactory is reinforced fiberglass in an epoxy resin. Current forms of fiberglass/epoxy plastic have been developed which can be molded or formed like sheet steel. Idealy, weight reductions of up to 60% can be achieved, if the substitution is on a density basis; however, 57 actual parts are designed to mechanical properties and, consequently, result in 30-40% weight reductions. To apply these materials to the Army's 2-1/2-ton and 5-ton product improved trucks requires the development of technology to produce these items.

4. OBJECTIVE

The program objective was to determine the production parameters required to manufacture the reinforced fiberglass hood/fender assembly for the M939 5-ton series trucks, and whether or not the reinforced assembly could perform in the military environment of extreme heat and cold and high humidity.

The current need to achieve high fuel economy requires that methods of reducing weight be investigated. As a start in vehicle weight reduction, it was decided to evaluate the change of material of certain components from steel to tailored reinforced fiberglass plastic. The original steel (low carbon, hot rolled, pickled and oiled with a minimum of temper 3) has a minimum yield strength of 36,000 PSI. The steel structure is a multipiece assembly welded and bolted together. The one-piece, reinforced-plastic hood/fender design is to have the same strength level as steel. This performance is to be expected with underhood temperatures ranging up to 250°F. Simplicity of design is to be achieved by the reduction of the number of pieces in the current steel hood/fender assembly.

5. CONCLUSIONS

1. Materials and configuration selected in conjunction with the finite element analysis are adequate.

2. The program, as conducted, did not provide the technology to go into full-scale production.

3. Vehicular testing was not conducted; therefore, no conclusions could be drawn as to whether or not the hood/fender assembly could perform in the military environment.

6. DISCUSSION

The material characterization data and the finite element analysis data were incorporated into the design shown on the drawings. The tooling was manufactured, but no parts were made, because the contract was terminated.

Ply lay-up sequence for the manufacture of the various components of the hood/fender assembly, using E-glass with an epoxy resin-NARMCO 5213 epoxy was as shown in Tables 1 and 2. The cure procedure was as follows:

a. Vacuum bag each mold to remove volatiles.

b. Pressurize to 28 in. of mercury.

c. Heat to 300°F for six hours and cool slowly to room temperature.

d. Remove pressure.

e. Remove panel and inspect.

The entire design was based on a flexural strength of 39,000 PSI at 200°F. This strength level allows the hood/fender assembly to function over the required lower temperature range of -50°F; the NARMCO 5213 resin system softening at temperature of 250°F and below.

A hood/fender assembly of these materials weighs 162 pounds ± 5%. The weight removed is 162 pounds ± 5% which amounts to a weight savings of 47%.

7. FINITE ELEMENT ANALYSIS

In order to assure that the proposed design will be at minimum weight and still provide the necessary strength level, a finite element analysis was made; a computer model was established. This model for the various hood/fender assembly elements is shown in figures 1 - 6. The computer program selected was NISA. Each element is numerically defined with the corrresponding node coordinates, shown in figures 1 - 6. The stress levels obtained in these cases were based on the modulus of elasticity of the material being considered.

The finite element analysis was conducted, using three different sets of input parameters. These are as follows:

a. The first is identified as load case A-1. The input parameters are:

(1) Material thickness is 0.125 inches.

(2) The load is 1,000 pounds uniformly distributed over the upper, outer hood panel surface.

This load is to simulate the transportation of five human beings (200 pounds each) lying flat on the surface of the hood. Loads resulting from the opening and closing of the hood/fender assembly are insignificant for consideration in the overall structural analysis. Their effect is localized at the handle and latch attachment points. These require reinforcement in the areas of high stress concentration.

b. The second is identified as load case B-1. The input parameters are:

(1) Material thickness is 0.100 inch.

(2) The load is 1,000 pounds, uniformly distributed over the upper, outer hood panel surface.

c. The third is identified as load case B-2. The input parameters are:

(1) Material thickness is 0.100 inch.

(2) The load is 500 pounds, simulating two men of 250 pounds each standing on the fender. Man no. 1 is standing on an area of 103 sq-in., located to the rear of the center of the fender, and man no. 2 is standing on an area of 97 sq-in. located forward of the center of the fender. Man no. 1 experts a downward force of 2.43 lb/sq-in. and man no. 2 exerts a downward force 2.56 lb/sq-in. Only one-half of the hood was analyzed, due to the symmetry about the longitudinal center line of the vehicle.

In figure 7 - 37 load case A-1, all of the various computer-generated stresses are shown. Transverse stresses (Sxx), longitudinal stresses (Syy), shear stresses (Sxy), maximum principal stresses (S_3 figure 35) and the Von mises stresses (Seq), figure 36, were calculated for all hood assembly panels. Figure 37 depicts the deformaiton of the hood. Because shell analysis was used for this, both tip and bottom surfaces of each panel were evaluated and the results are shown. The stress contours shown in each figure represent lines of equal stress.

Figure 38 depicts the hood deformation arising from the parameters of load case B-1. Figures 39 - 68 show the stress levels generated by the analysis for this load case B-1.

Figure 69 depicts the hood deformation arising from the parameters of load case B-2. It should be noted that most of the deformation is on the fender, because the load application is directly to the fender.

Figure 70 - 79 show the stress levels generated by the analysis for this load case B-2.

None of the stresses generated by the computer are excessive for this load case B-2.

Based on the input loads and the strength of the reinforced plastic combination selected, the hood/fender assembly material was selected based on a flexural strength at 250°F and 39,000 PSI and a flexural modulus of 2.2 x 10^6 PSI. The actual material ply lay-up sequences were based on the material characterization study.

8. MATERIAL CHARACTERIZATION STUDY

8.1. Test Material

To achieve maximum strength at minimum weight, a material characterization study was conducted. The basic material was an E-glass fabric/epoxy prepreg composed of eight plies, compression molded together, using NARMCO 5213 epoxy. Three different fabric orientations were evaluated with a final thickness of 0.080 after the cure cycle. In each case, the cure cycle was as follows:

a. The air in the mold was evacuated.

b. The dies were heated to 300°F.

c. The plaque was placed under pressure and held at 300°F for 45 minutes.

d. The mold was air cooled to room temperature.

e. At room temperature, the plaque was removed and inspected.

The following material combinations were manufactured into test plaques and subjected to mechanical property tests:

a. Combination identified as no. 1 and J were laid up, using the following fiberglass orientation sequence: 8 plies (0°,90°, 0°, 90°) 2s.

b. Combinations identified as no. 2 and C were laid up using the following fiberglass orientation sequences: 8 plies (+45°, -45°, +45°) 2s.

c. A combination identified as no. 4 was laid up using the following fiberglass orientation sequence: 10 pliers (0°, 90°, +45°, -45°).

d. A combination identified as K was laid up as follows: (0°, 90°, ±45°) 2s.

8.2 Test Equipment and Procedures

Test equipment utilized in conducting the test to ASTM-D-790 was an Instron Model 1123. The samples were conditioned for a minimum of 24 hours at 72°F with relative humidity at 50% for room temperature evaluation; samples were also conditioned at -40°F and 200°F. The cross head which applied the load was moved at a speed of 0.05 inch a minute. The following data were obtained from plaques 1, 2 and 4: flexural strength and flexural modulus. See Tables 3,4,5,6 and Chart no. I. The following data were obtained from plaques C, J and K: Yield strength, ultimate tensile strength, tensile modulus, elongation. Results are shown in Table 6. Based on the data obtained in the flexural testing to ASTM-D-790, the flexural strength and lexural modules are greater at sub-zero temperatures than at elevated temperatures (250°F for this application). The data obtained rank the materials as follows:

a. 0, 90° orientation

b. 0, 90°, 45° orientation, maybe 90°, 90° ±45°

c. ± 45° orientation

The results also indicate that materials with (0°, 90°) and (-0°, 90°, ± 45°) will provide the minimum required strength at elevated temperatures. The room temperature properties are more than adequate for most operating environments. Because the contract was terminated, neither impact nor fatigue data were obtained.

TABLE 1. Lay-up Sequence; Hood, Fenders, Side Panels, and Center Panel

(0,90°)
+45°
-45°
(0,90°)
(0, 90)
90°
(0, 90)
+45
-45
(0,90)
N.A. ———————————— N.A. (Neutral axis of part)
(0,90)
-45
+45
(0,90)
90
(0,90)
(0,90)
-45°
+45°
(0,90°)

Part thickness (before curing) = 0.210°
Part thickness (after curing) = 0.190°

TABLE 2. Lay-up Sequence; Hood Support

(0,90°)	
(0,90°)	E-Glass/5213 epoxy fabric
(0,90°)	
(0,90°)	
+45°	
-45°	E-Glass/5213 epoxy unidirectional
(0,90°)	E-Galss/5213 epoxy fabric
+45°	
-45°	E-Glass/5213 epoxy mnidirectional
(0,90°)	
N.A.	N.A. (Neutral axis of part)
(0,90°)	
-45°	
+45°	
(0,90°)	
-45°	
+45°	
(0,90°)	
(0,90°)	
(0,90°)	
(0,90°)	

Part thickness (before curing) = 0.196 in.
Part thickness (after curing) = 0.180 in.

TABLE 3.

FLEXURAL PROPERTIES PANEL 1

SPECIMEN \ Test Temperature	-40°F		72°F		+200°F	
	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6
1	87,800	3.82	74,700	3.63	50,200	2.71
2	93,200	3.73	80,500	3.35	45,300	2.75
3	87,000	3.53	80,500	3.54	46,000	2.62
4	103,000	3.36	71,200	3.53	46,600	2.74
5	91,000	3.60	71,600	3.53	51,800	2.81
6	101,000	3.83	82,600	3.67	49,000	2.74
7	124,000	3.67	79,000	3.67	44,000	2.70
8	99,900	3.38	80,400	3.76	45,500	2.70
9	101,000	3.74	76,400	3.51	52,900	2.93
10	105,000	3.54	44,900	3.49	46,900	2.84
AVERAGE	99,290	3.62	77,960	[illegible]	47,820	2.754

TABLE 4. **FLEXURAL PROPERTIES PANEL 2**

Test Temperature / SPECIMEN	-40° F		72° F		+200° F	
	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6	FLEXURAL STENGTH PSI	FLEXURAL MODULUS PSI X 10^6
1	63,500	2.47	52,000	2.41	27,900	1.09
2	63,700	2.24	45,300	2.13	29,100	1.08
3	48,900	2.37	47,600	2.27	32,300	1.13
4	62,500	2.57	49,000	2.26	30,400	1.28
5	65,300	2.75	49 500	2.20	30,200	1.12
6	62,200	2.67	52,700	2.25	35,900	1.49
7	64,000	2,58	50,400	2.32	35,900	1.36
8	66,700	2.69	51,500	2.29	34,900	1.76
9	61,500	2.52	50,800	2.36	34,500	1.54
10	66,500	2.82	51,600	2.38	35,400	1.59
AVERAGE	63,480	2.568	50,040	2.287	32,650	1.344

TABLE 5.

FLEXURAL PROPERTIES PANEL 4

Test Temperature / SPECIMEN	-40° F		72° F		+200° F	
	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6	FLEXURAL STRENGTH PSI	FLEXURAL MODULUS PSI X 10^6
1	78,900	3.58	73,400	3.17	39,300	2.24
2	78,000	3.54	69,600	2.97	37,900	3.32
3	74,500	3.52	74,400	3.29	38,700	2.26
4	79,100	3.61	63,400	3.17	40,000	2.38
5	78,100	3.60	67,200	3.19	41,600	2.52
6	91,300	3.52	83,600	3.03	58,500	2.58
7	85,600	3.44	73,800	2.95	58,800	2.57
8	85,800	3.47	69,400	3.00	59,500	2.61
9	85,500	3.43	76,000	3.13	59,200	2.57
10	93,000	3.52	79,200	3.02	56,900	2.62
AVERAGE	83,480	3.523	73,000	3.092	49,040	2.467

TABLE 6

TENSILE TEST DATA*

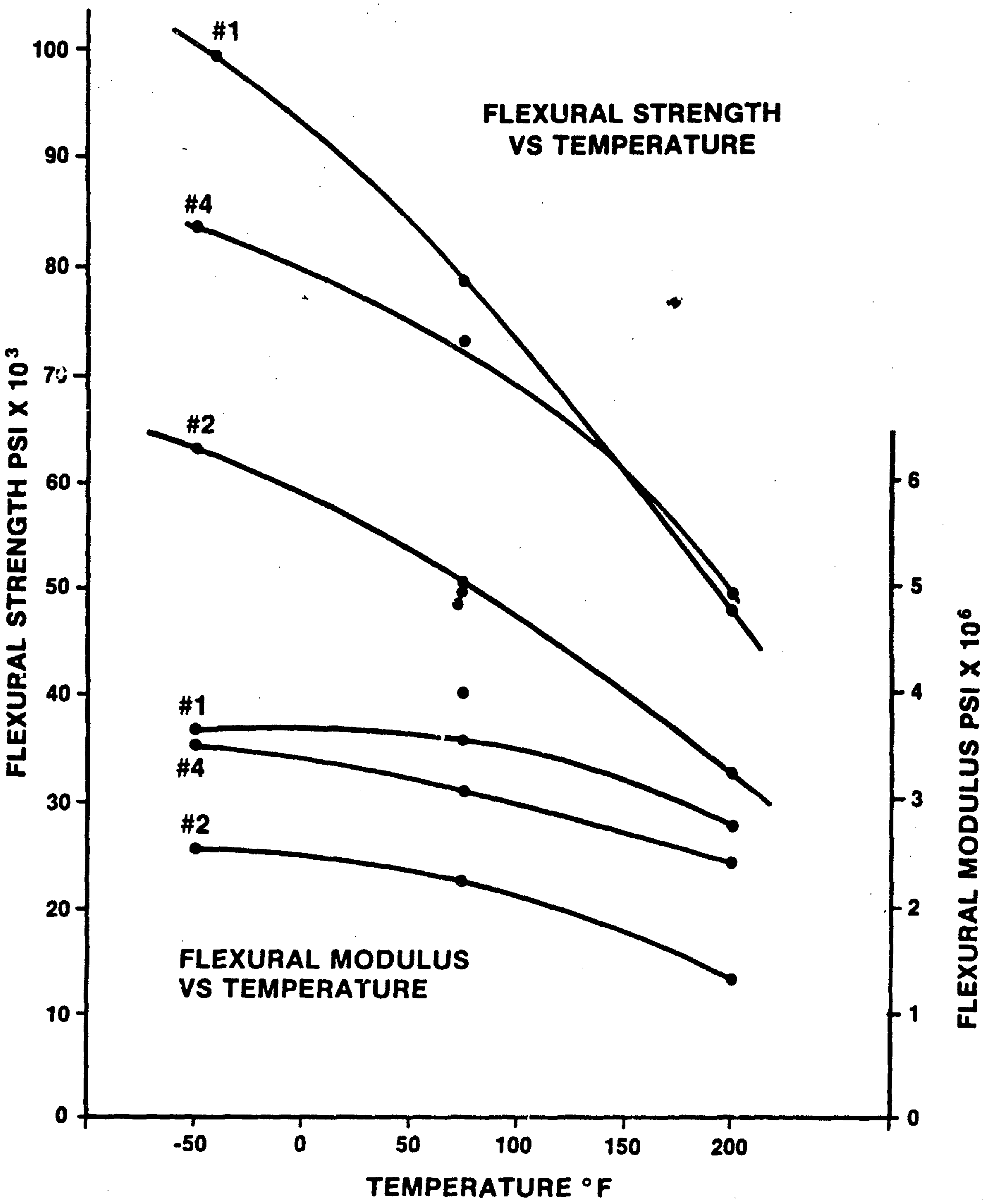
Samples removed from Plaque J

SAMPLE	YIELD STRENGTH PSI	ELONGATION %	ULTIMATE STRENGTH PSI	ULTIMATE STRAIN %	TENSILE MODULUS PSI X 10
1	27.930	2.25	53,350	3.30	4.974
2	15,490	1.63	48,010	2.85	6.215
3	19,410	1.60	50,170	2.753	5.464
4	17,290	1.70	50,090	2.980	7.125
5	15,440	1.53	51,760	2.789	7.820
AVERAGE	19,112	1.74	50,676	2.93	6.3196
Samples removed from Plaque C					
1			36,000	2.67	
2		2.752	40,010	3.10	
3		3.032	40,340	2.58	
4		3.706	40,190	2.15	
5		3.650	43,770	1.92	
AVERAGE		3.315	40,054	2.48	
Samples removed from Plaque K					
1	15,270	2.272	45,310	3.55	5.452
2	16,200	2.228	48,480	3.754	3.871
3	20,960	1.890	51,190	3.236	3.888
4	----	---	50,260	4.638	---
5	18,360	1.70	46,960	2.909	5.417
AVERAGE	17,697	2.022	48,440	3.62	4.657

*Test temperature: 72° F

CHART I.

FIBERGLASS/EPOXY PLASTIC WITH VARIOUS PLY ORIENTATIONS



9. PROTOTYPE TOOLING DEVELOPMENT

The tooling for the manufacture of both 2-1/2-ton and 5-ton truck hoods was based on the use of an actual steel hood/fender assembly furnished by the US Army Tank-Automotive Command. They were disassembled to be used as master tooling aids. The following components were used in the mold development:

a. Hood Outer Panel--the total outer panel including the right, left and center pieces wree used as a single unit upon which to generate the plaster tooling necessry to manufacture the plastic component.

b. Right hand side fender panel.

c. Right hand side vertical panel.

d. Left hand side fender panel.

e. Left hand side vertical panel.

The surface of each panel is a mirror image of the required engineering section. Using these, individual molds were made using the described procedure.

Each panel was internally crated using wood reinforcement to provide a solid structure. Each reinforced panel was enclosed with high grade wood to provide a completely integrated box. Vertical and horizontal surfaces were constructed to provide additional support to the plastic tooling during the lamination procedures. Each box was airtight, so that leakage did not occur during the mold fabrication.

Molds were laminated to duplicate the exact outer surface of the steel panels. Layers of hand-laid glass cloth were impregnated with high temperature epoxy.

This was followed by the addition of 12 layers of additional reinforcement for the mold. These reinforcements were applied in two steps.

Six layers were hand-laid, impregnated with epoxy and vacuum bagged for 24 hours. At least 24 layers of fiberglass impregnated with high temperature epoxy resins were used to create the plastic tools.

Vacuum bagging was used to conform those layers to the outer surface of the steel panels. A vacuum of at least 23 in. Hg was applied for a period of at least 24 hours. Vacuum was applied after the lamination of every six fiberglass layers. After this period, the molds were hard enough to prevent spring-back from the master tool surface and the bottom surface of the mold. This resulted in a completely integrated mold with vertical reinforcements.

The overall assembly was then cured at 300°F for three hours. The woodframe was removed from each mold at the end of the cooling cycle. The molds were inspected for any delamination or imperfections. The bottom surface of each mold was then machined flat to provide an even surface for future part lay-up. A flat plastic panel was cut and attached to the bottom surface of the mold. This approach resulted in high quality tooling that can be used for the fabrication of several composite components.

Aluminum tooling was designed and fabricated for all the various components of the grille opening panels.

Photographs of the mold manufacturing process are shown in figures 100-110.

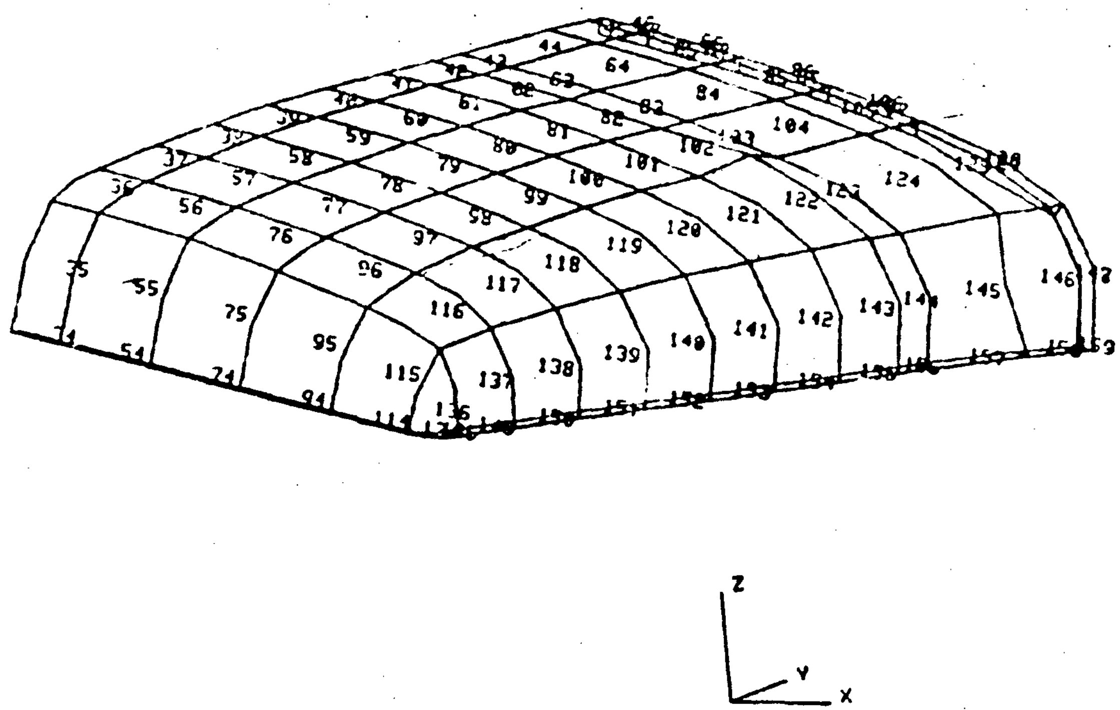


Figure 1. Finite Elements For Upper Outer Hood Panel

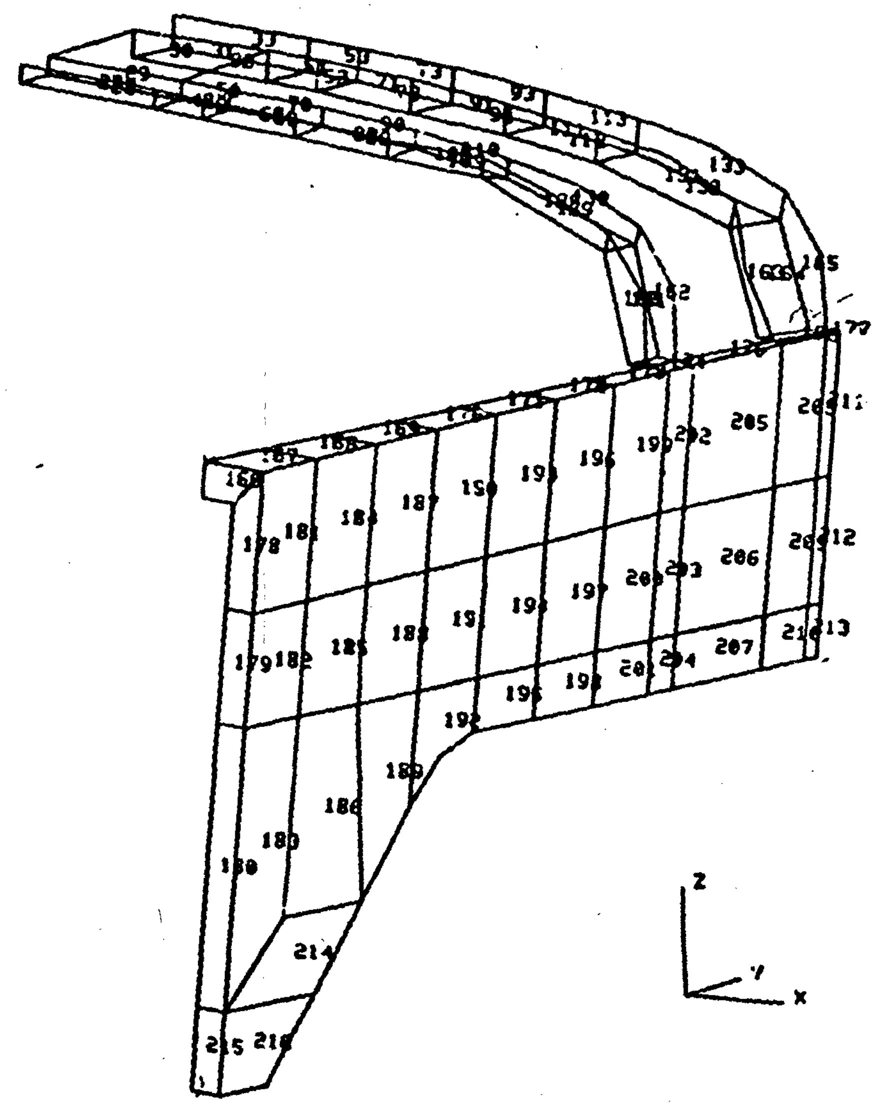


Figure 2. Finite Elements For Inner Reinforcement Panel, And Side Panel

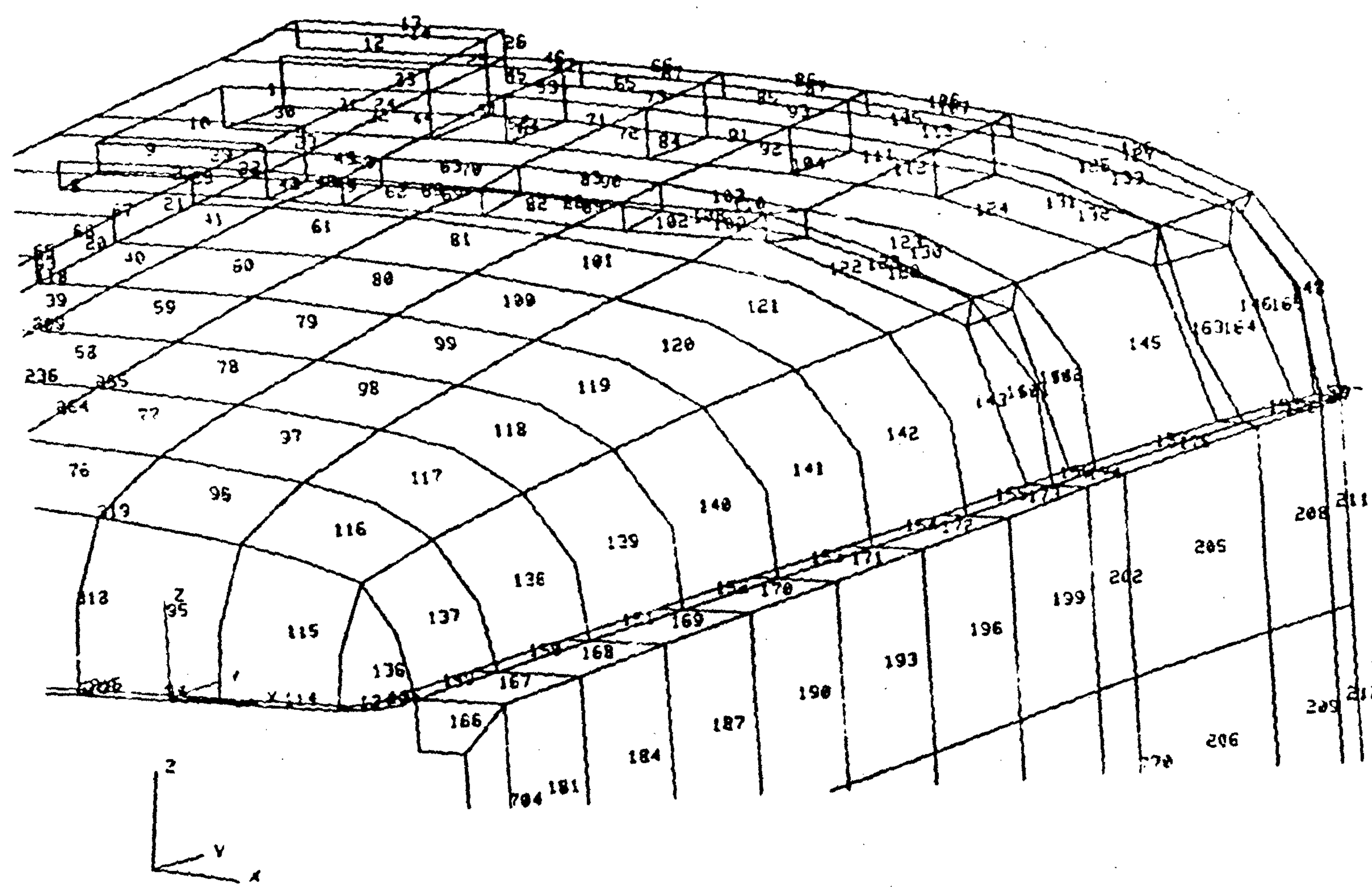


Figure 3. Finite Elements For Boundaries Between Upper Outer Panel, Side Panels & Grill Panel

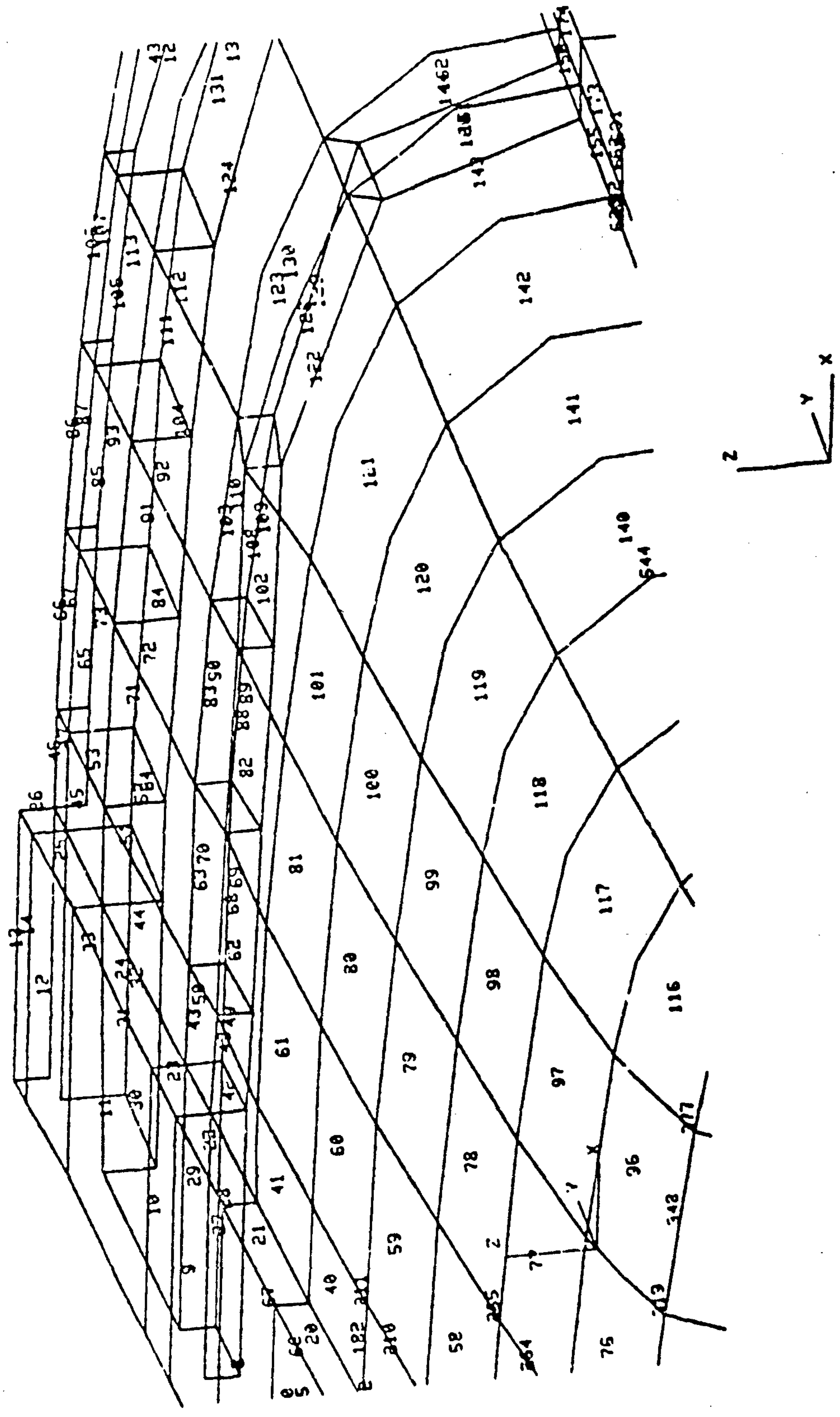


Figure 4. Details Of Finite Elements Of Reinforcing Panels

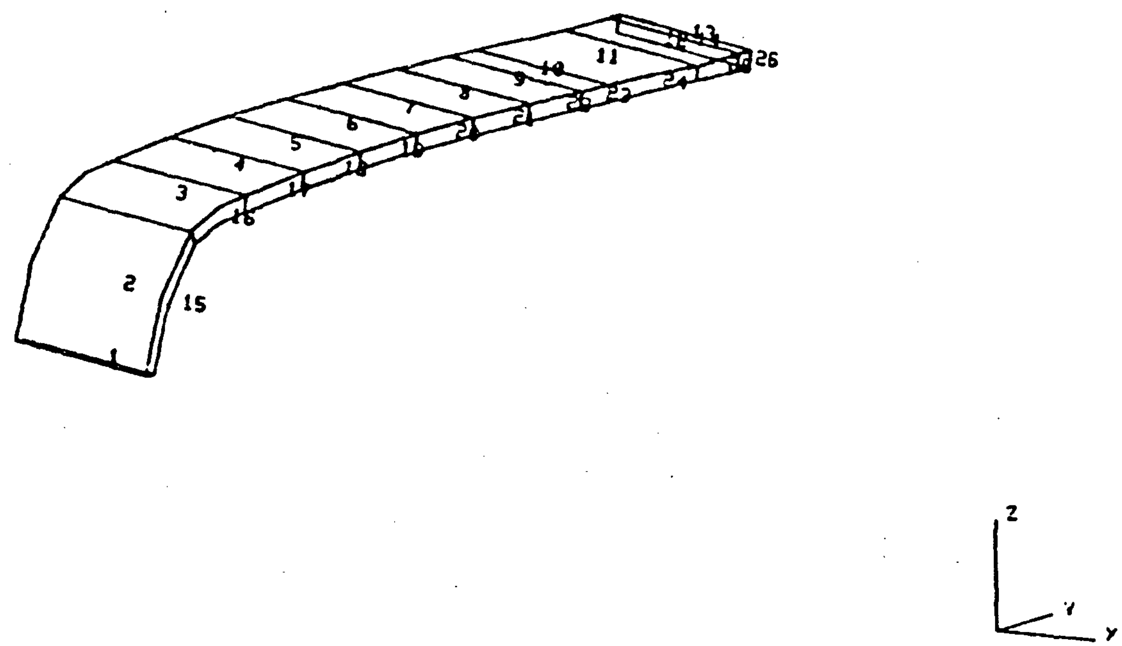


Figure 5. Finite Elements For Center Piece Of Upper Outer Hood Panel

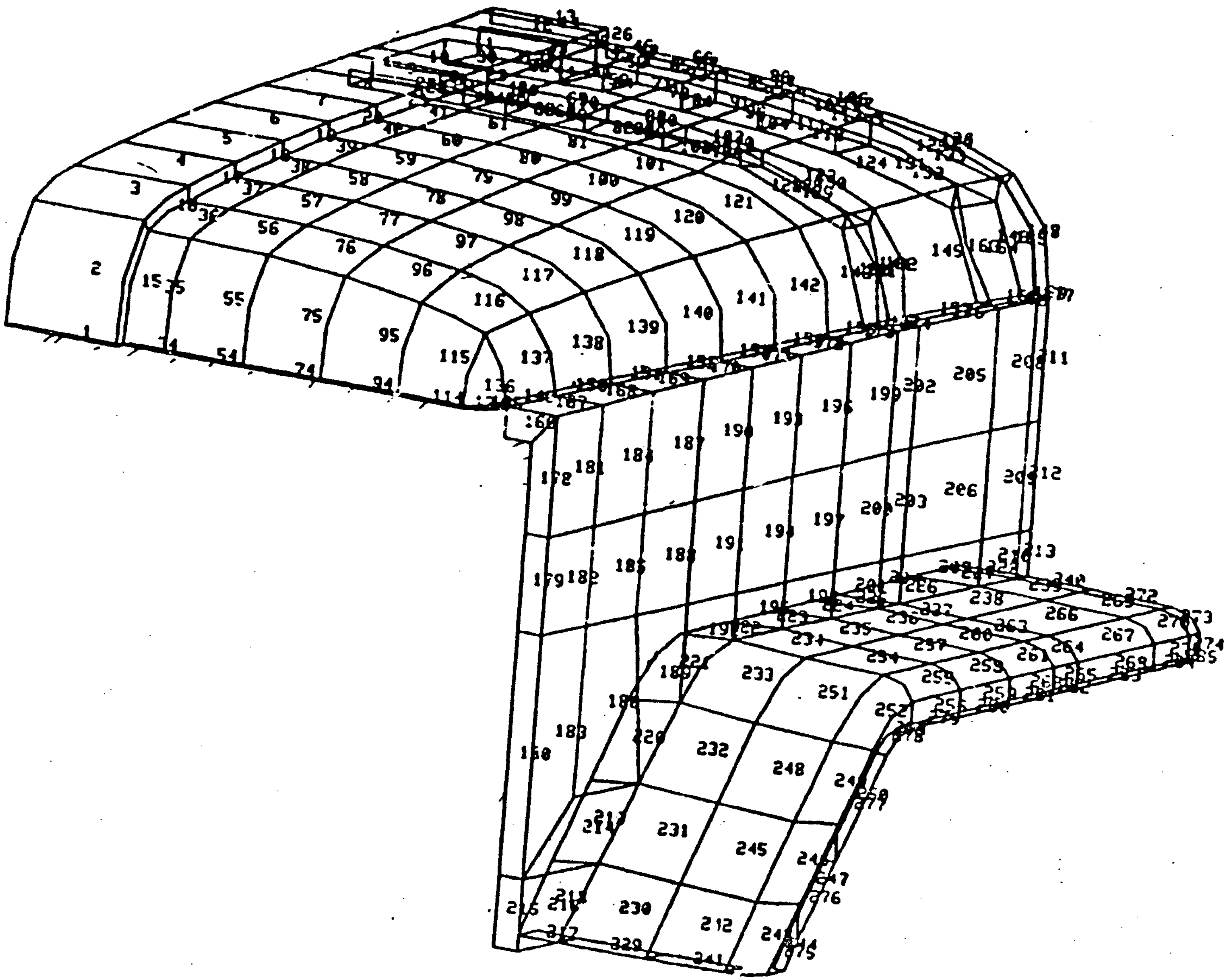
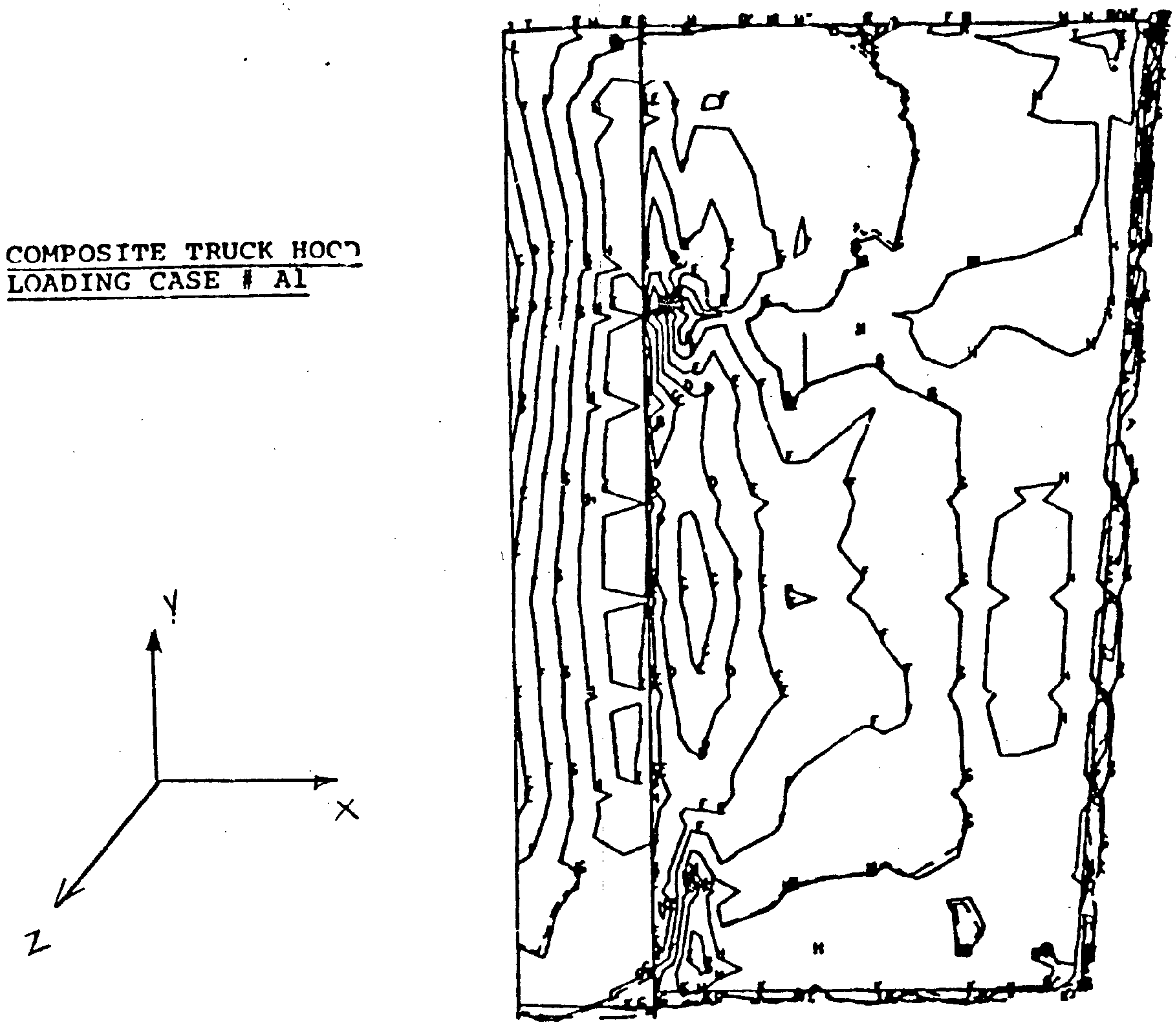


Figure 6. Finite Elements Identification For Overall Hood Assembly



STRESS CONTOURS (psi)

A = -3,113

B = -2,591

C = -2,669

D = -1,547

E = -1,023

F = -503

G = 20

H = 54

I = 1,063

J = 1,585

K = 0,000

Figure 7. Transverse Stresses (Sxx), Top Surface Of Truck Hood

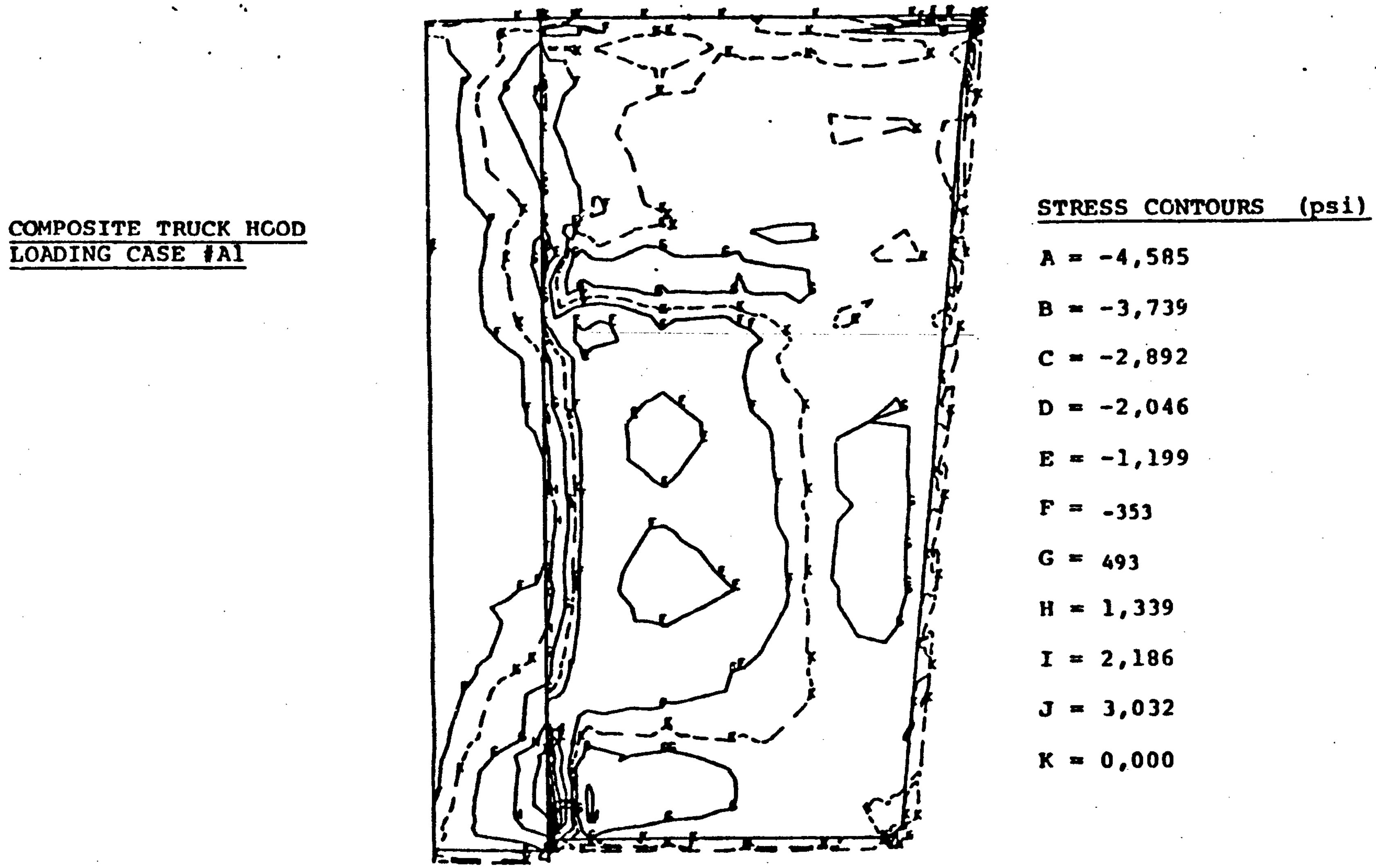
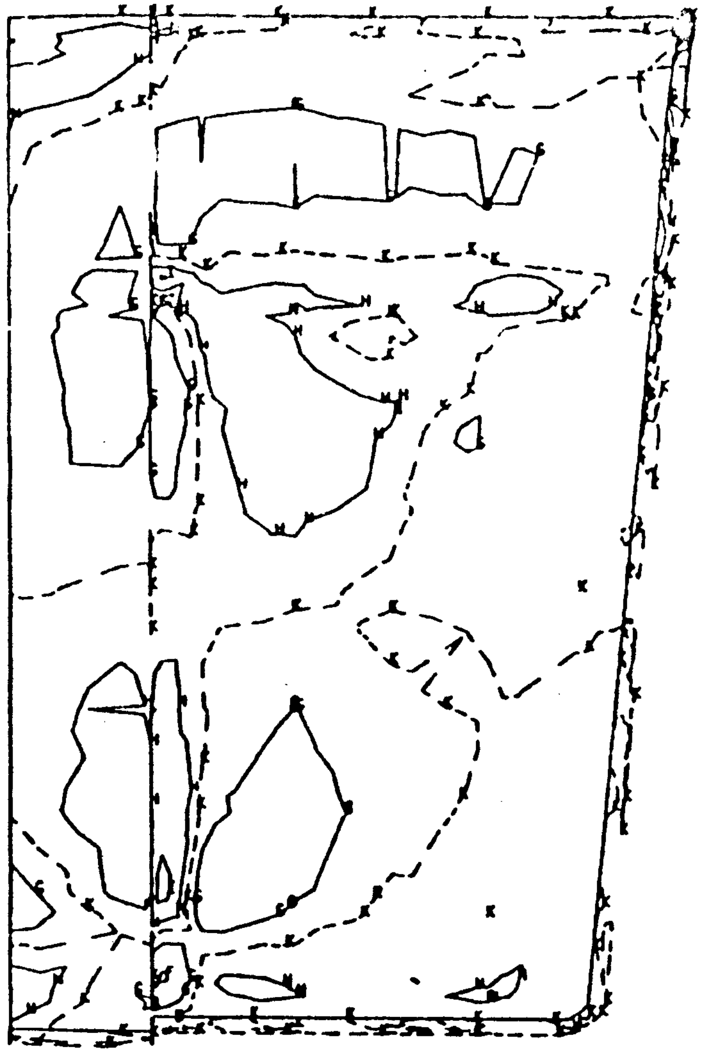


Figure 8. Longitudinal Stresses (Syy), Top Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE # A1



STRESS CONTOURS (psi)

A = -2,954

B = -2,500

C = -2,046

D = -1,591

E = -1,137

F = -683

G = -230

H = 225

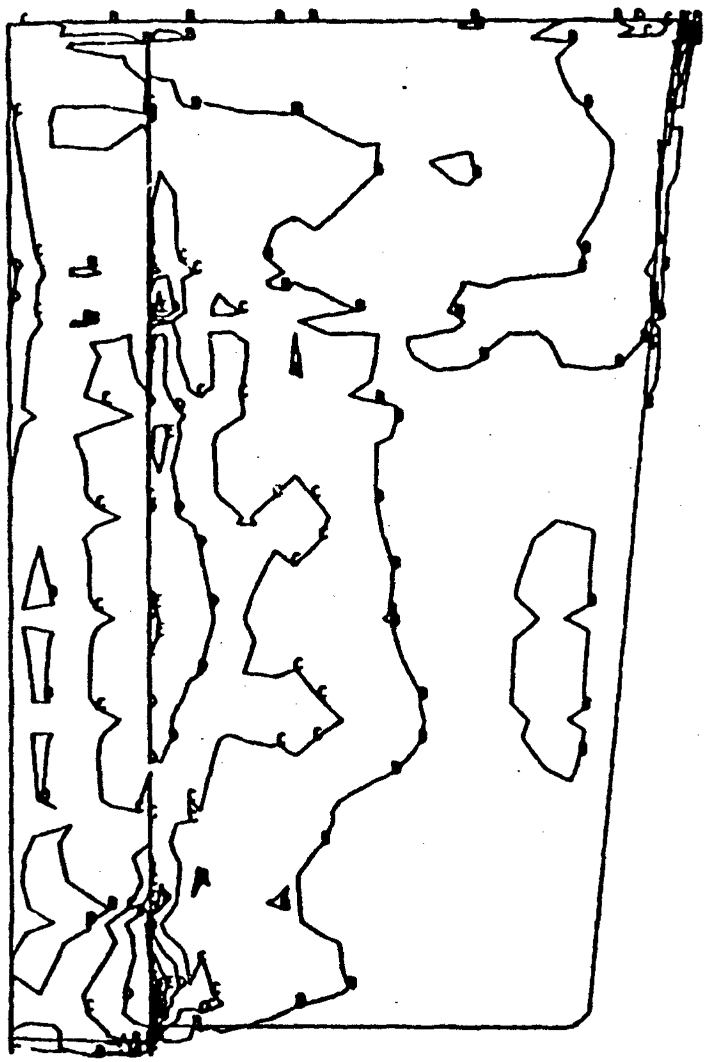
I = 679

J = 1,133

K = 0,000

Figure 9. Shear Stresses (Sxy), Top Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE #A1



STRESS CONTOURS (psi)

A = 0,000

B = 6,401

C = 1,280

D = 1,920

E = 2,560

F = 3,200

G = 3,841

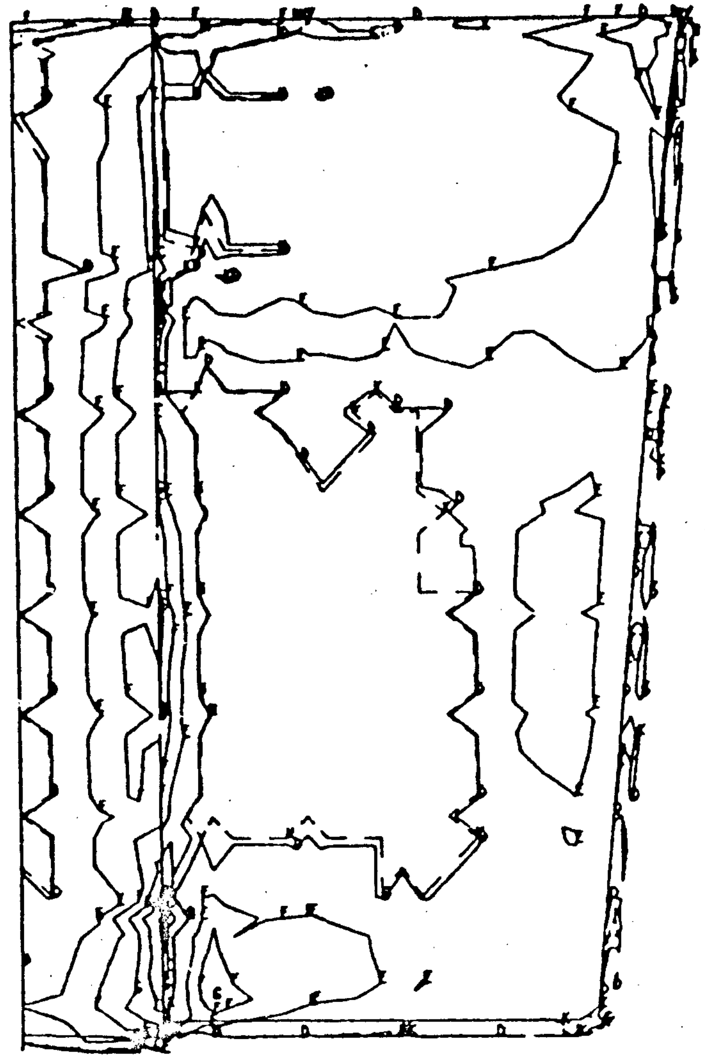
H = 4,481

I = 5,121

J = 5,761

Figure 11. Von Mises Equivalent Stresses (S_{eq}). Top Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE #A1



STRESS CONTOURS (psi)

A = -1,823

B = -1,207

C = -590

D = 26

E = 643

F = 1,259

G = 1,876

H = 2,492

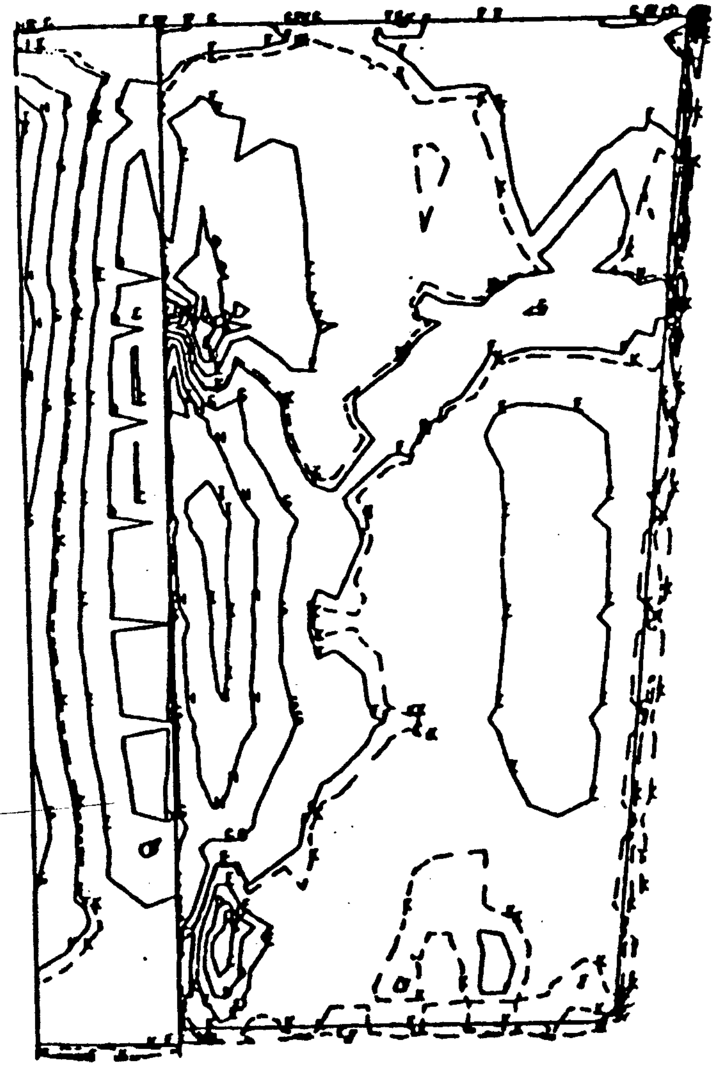
I = 3,109

J = 3,725

K = 0,000

Figure 10. Maximum Principal Stresses (S_3), Top Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE #A1



STRESS CONTOURS (psi)

A = -2,977

B = -2,363

C = -1,750

D = -1,136

E = -5,230

F = 90

G = 704

H = 1,317

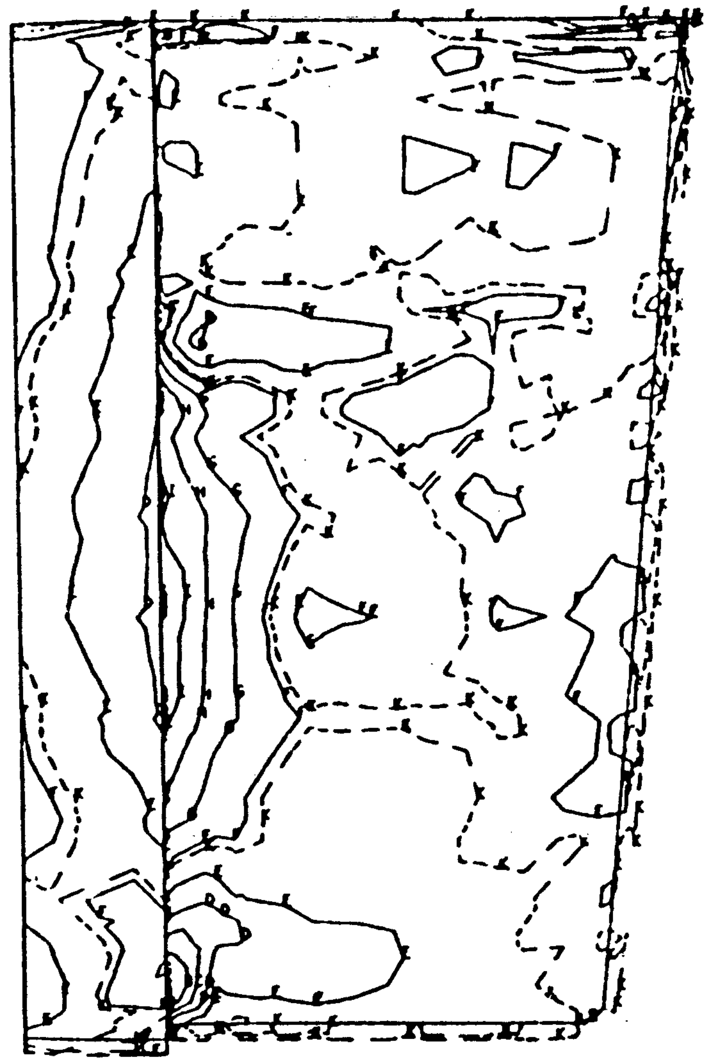
I = 1,930

J = 2,544

K = 0,000

Figure 12. Transverse Stresses (Sxx), Bottom Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE #A1



STRESS CONTOURS (psi)

A = -3,564

B = -2,817

C = -2,069

D = -1,322

E = -575

F = 172

G = 918

H = 1,666

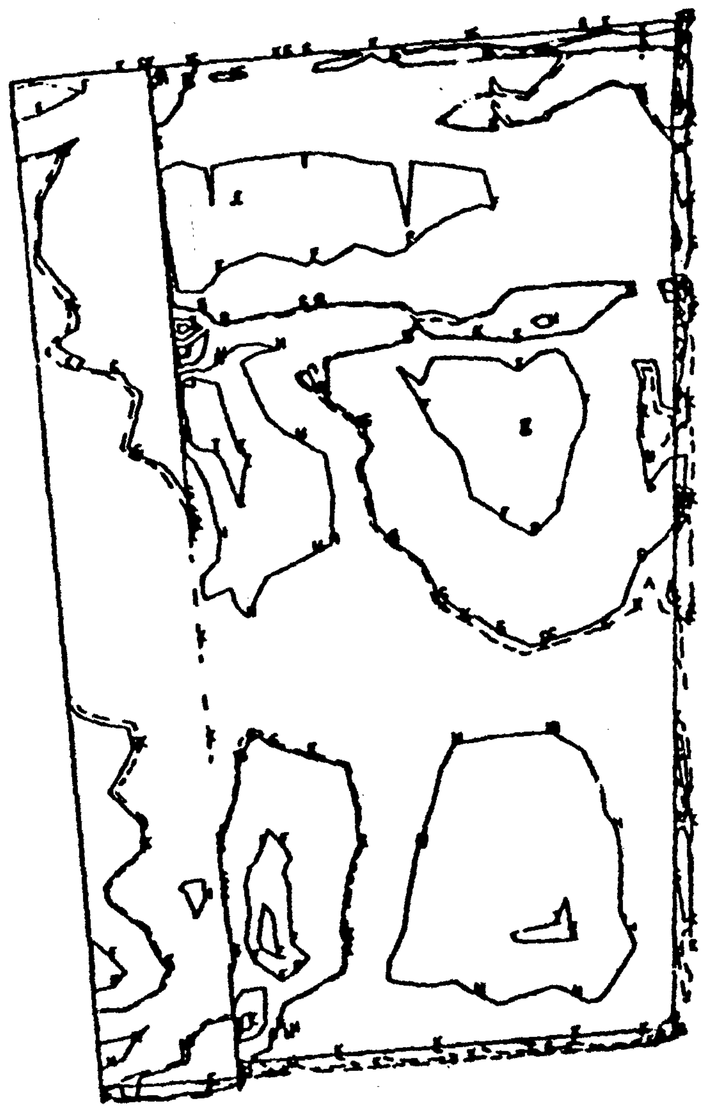
I = 2,413

J = 3,160

K = 0,000

Figure 13. Longitudinal Stresses (Syy), Bottom Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE #A1



STRESS CONTOURS (psi)

A = -1,826

B = -1,525

C = -1,223

D = -921

E = -620

F = -318

G = -17

H = 284

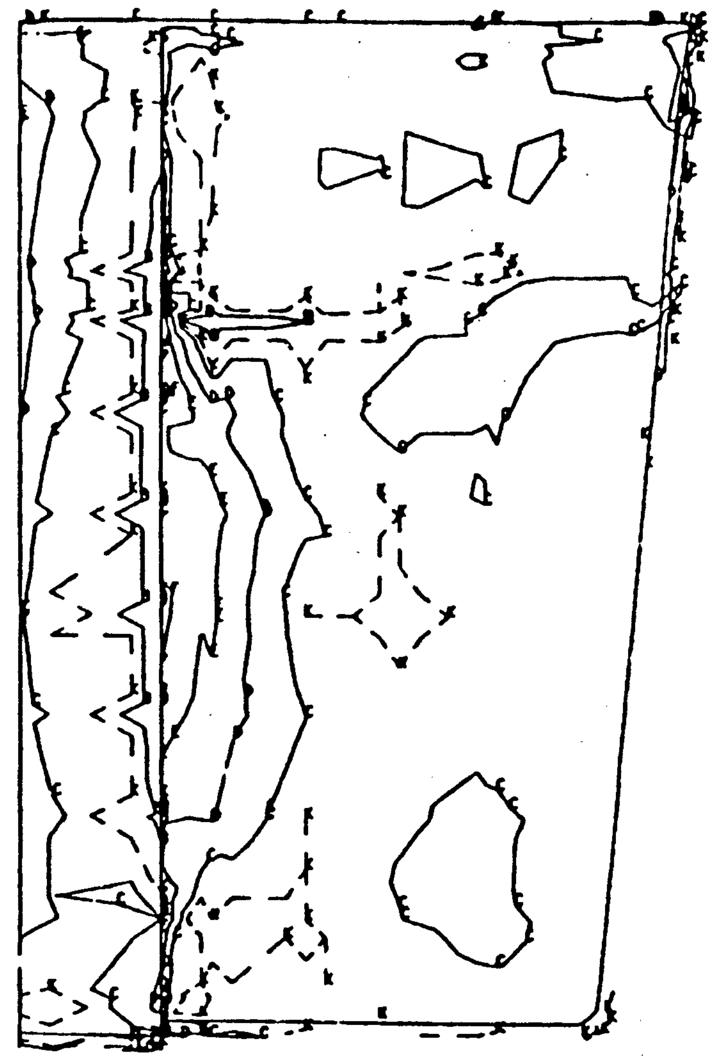
I = 586

J = 887

K = 0,000

Figure 14. Shear Stresses (Sxy), Bottom Surface Of Truck Hood

COMPOSITE TRUCK HOOD
LOADING CASE #A1



STRESS CONTOURS (psi)

A = -1,252

B = -424

C = -403

D = 1,231

E = 2,058

F = 2,886

G = 3,714

H = 4,541

I = 5,369

J = 6,197

K = 0,000

Figure 15. Maximum Principal Stresses (S_3), Bottom Surface Of Truck Hood

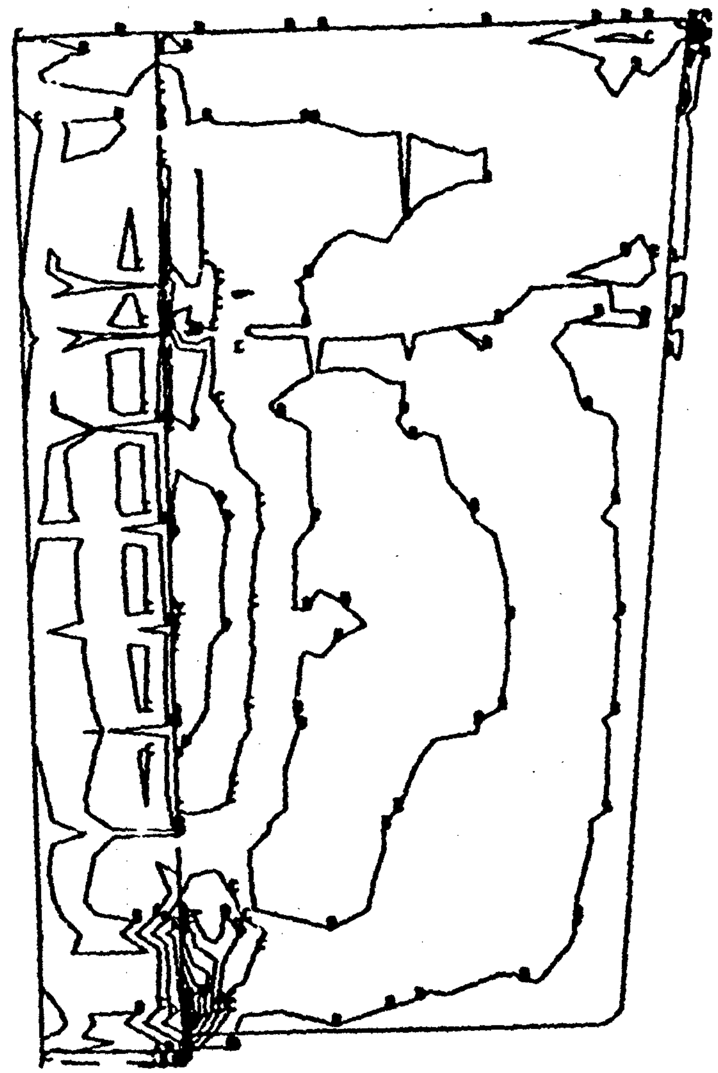


Figure 16. Von Mises Equivalent Stresses (S_{eq}), Bottom Surface Of Truck Hood

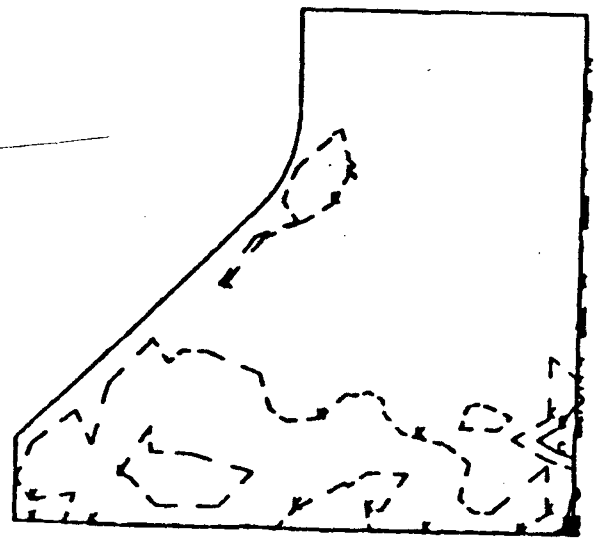
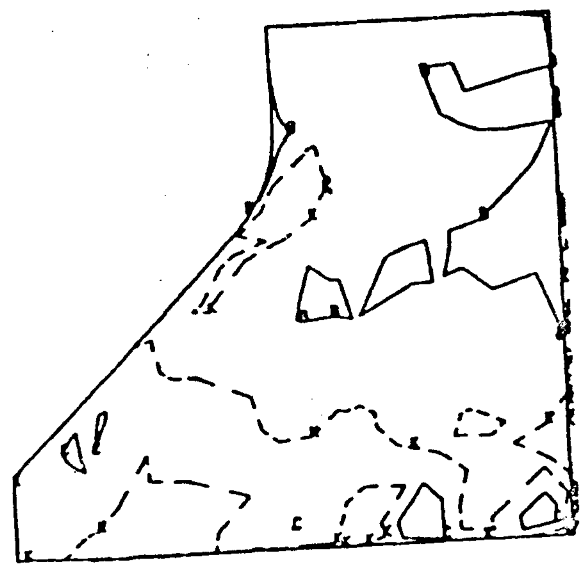


Figure 17. Transverse Stress Contours (Sxx) Of Side Panel, Top Surface, Load Case A1



STRESS CONTOURS (psi)

A = 17.03

B = -5.612

C = 5.805

D = 17.22

E = 28.64

F = 40.05

G = 51.47

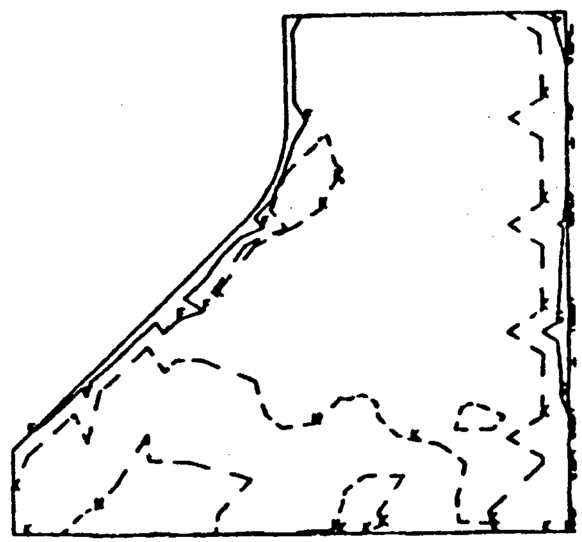
H = 62.89

I = 74.31

J = 85.72

K = 0.000

Figure 18. Longitudinal Stress Contours (Syy) Of Side Panels, Top Surface, Load Case A1



STRESS CONTOURS (psi)

A = 31.10

B = 25.05

C = 18.99

D = 12.93

E = -6.881

F = 82.50

G = 5.231

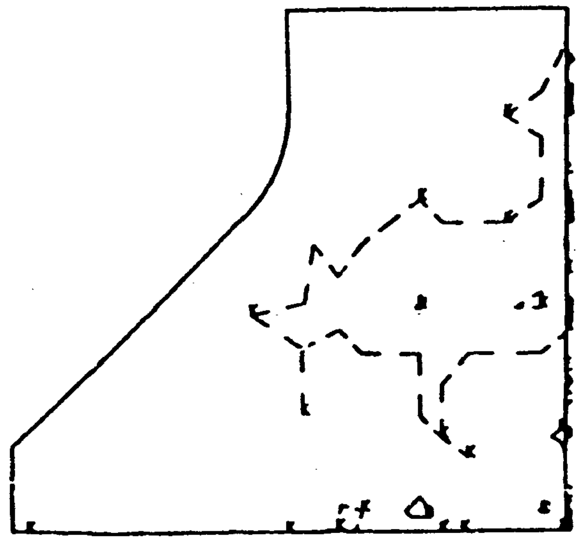
H = 11.28

I = 17.34

J = 23.40

K = 0.000

Figure 19. Shear Stress Contours (Sxy) Of Side Panels, Top Surface, Load Case A1



STRESS CONTOURS (psi)

A = -5.315

B = 25.49

C = 56.30

D = 87.11

E = 117.9

F = 148.7

G = 179.2

H = 210.3

I = 241.1

J = 271.9

K = 0.000

Figure 20. Maximum Principal Stresses (S_2) Of Side Panels, Top Surface, Load Case A1

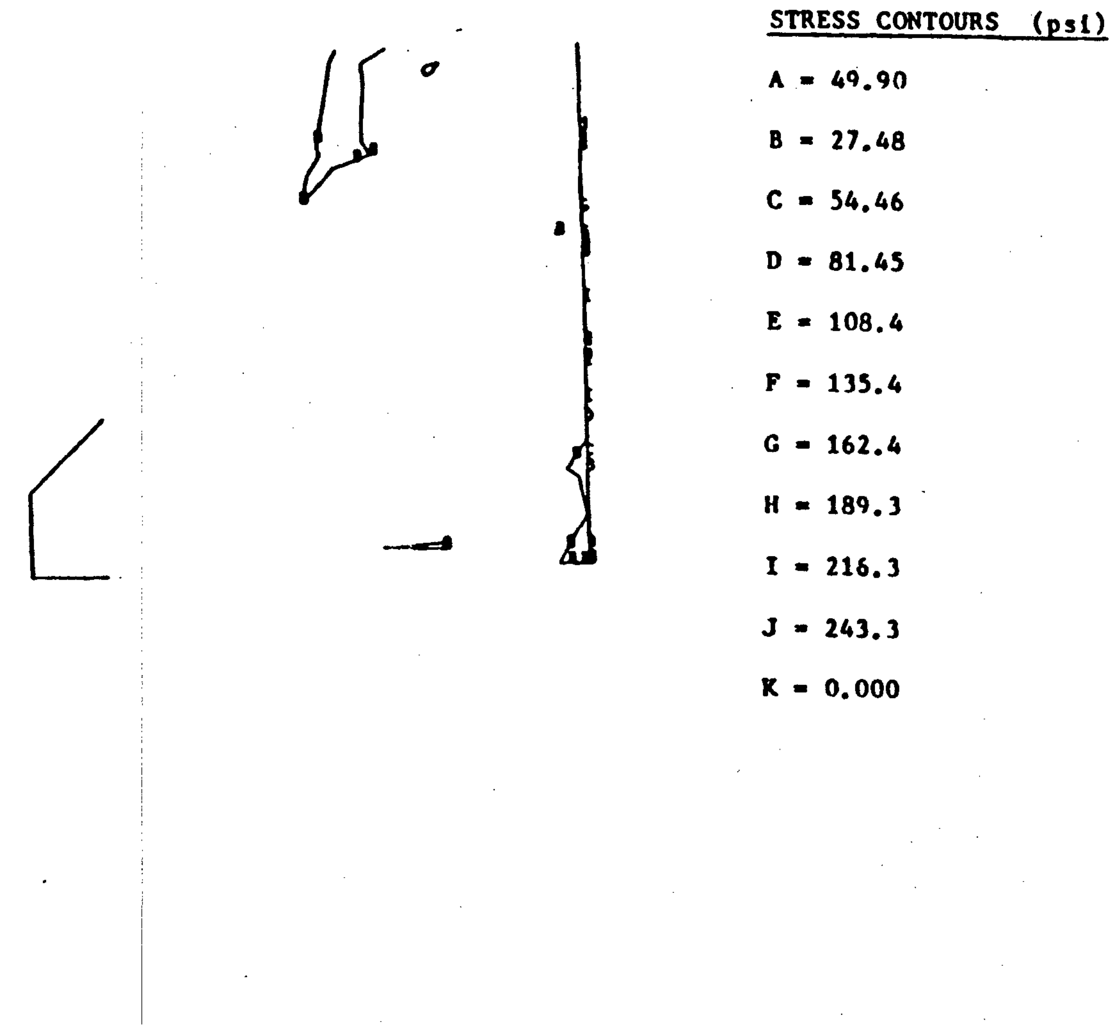
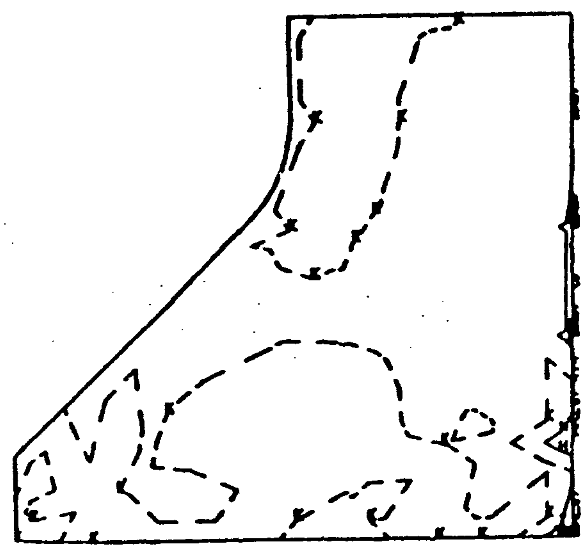


Figure 21. Von Mises Equivalent Stresses (Seq) Of Side Panel, Top Surface, Load Case A1



STRESS CONTOURS (psi)

A = 264.0

B = 228.6

C = 193.5

D = 158.3

E = 123.0

F = 87.82

G = 52.57

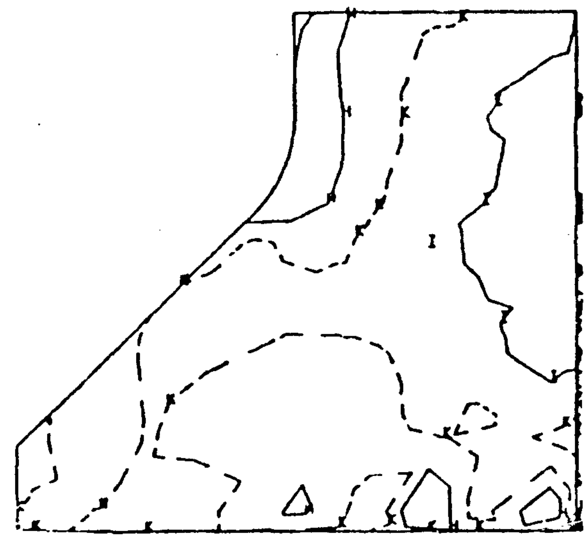
H = 17.32

I = 17.92

J = 53.16

K = 0.000

Figure 22. Transverse Stress Contours (Sxx) Of Side Panel, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = 84.85

B = 73.47

C = 62.09

D = 50.71

E = 39.33

F = 27.95

G = 16.57

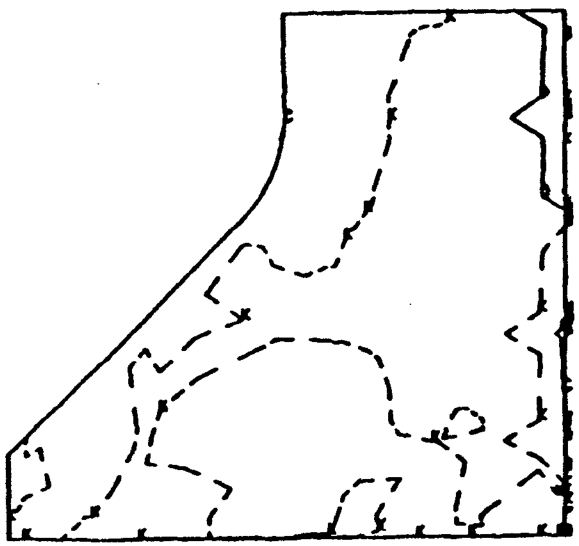
H = -5.189

I = 6.191

J = 17.57

K = 0.000

Figure 23. Longitudinal Stress Contours (Syy) Of Side Panels, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = 16.91

B = 10.89

C = -4.866

D = 1.159

E = 7.185

F = 13.21

G = 19.23

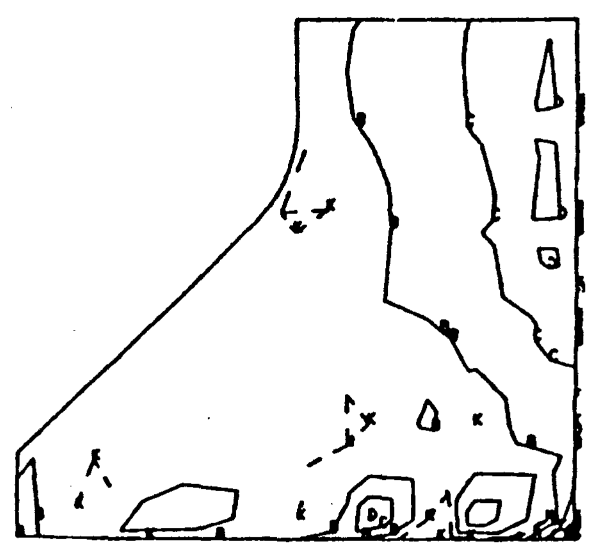
H = 25.26

I = 31.28

J = 37.31

K = 0.000

Figure 24. Shear Stress Contours (Sxy) Of Side Panels, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = -3.613

B = 7.332

C = 18.27

D = 29.22

E = 40.17

F = 51.11

G = 62.06

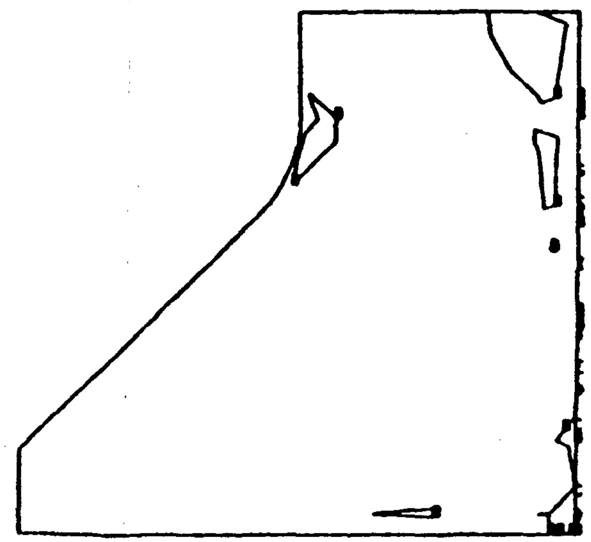
H = 73.00

I = 83.95

J = 94.90

K = 0.000

Figure 25. Maximum Principal Stresses (S_3) Of Side Panel, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = 47.20

B = 27.48

C = 54.50

D = 81.52

E = 108.5

F = 135.5

G = 162.5

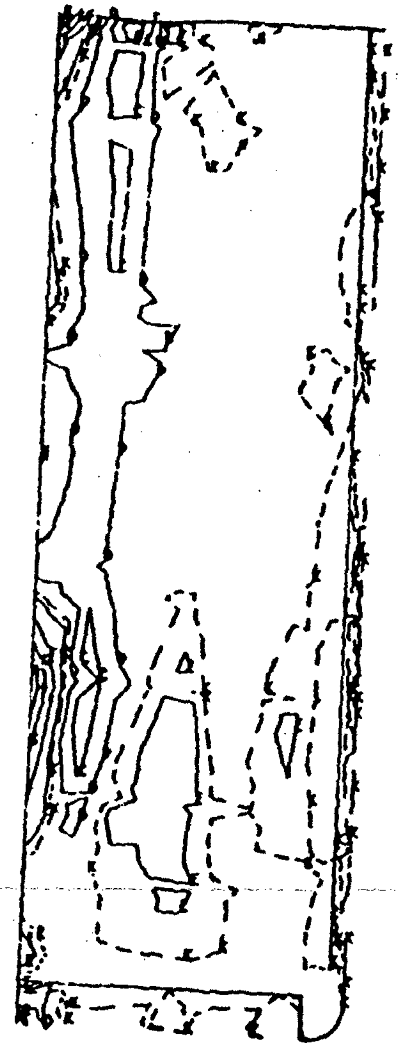
H = 189.5

I = 216.6

J = 243.6

K = 0.000

Figure 26. Von Mises Equivalent Stresses (Seq) Of Side Panel, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = 59.43

B = 23.0

C = 13.41

D = 49.83

E = 86.25

F = 122.6

G = 159.1

H = 195.5

I = 231.9

J = 168.3

K = 0.000

Figure 27. Transverse Stress Contours (Sxx) Of Side Fender, Top Surface, Load Case A1

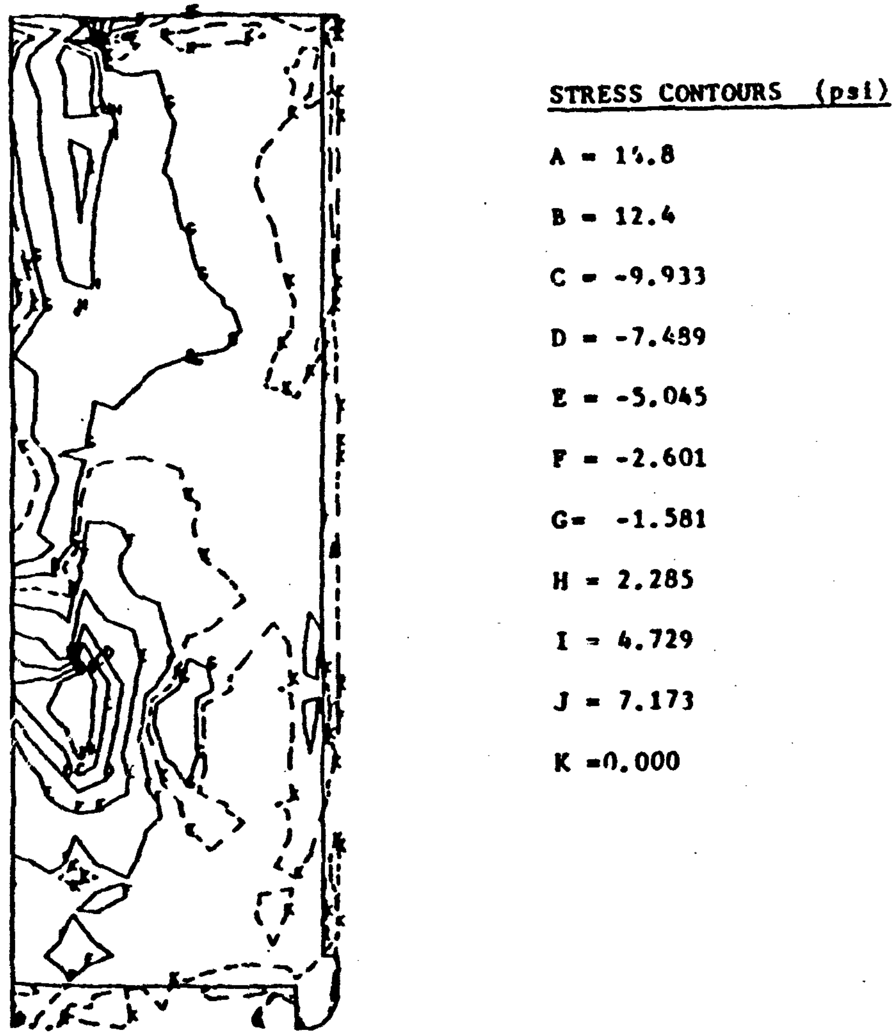
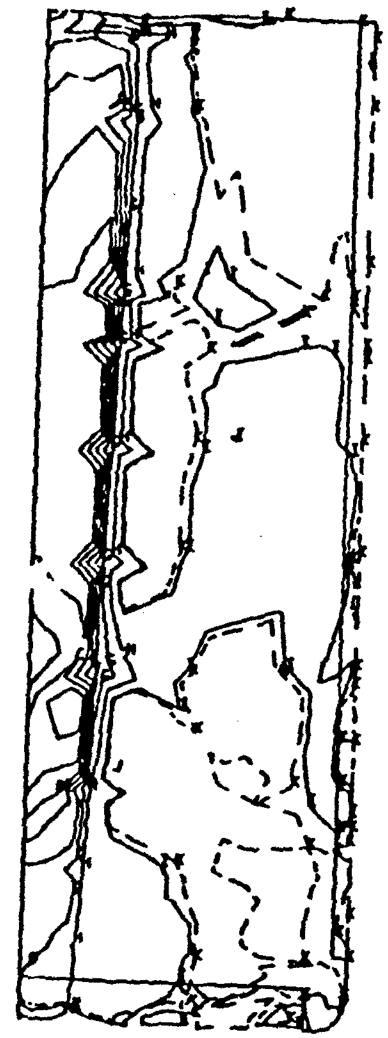


Figure 28. Longitudinal Stress Contours (Syy) Of Side Fender, Top Surface, Load Case A1



STRESS CONTOURS (psi)

A = 12.31

B = 10.79

C = -9.279

D = -7.760

E = -6.241

F = -4.722

G = -3.203

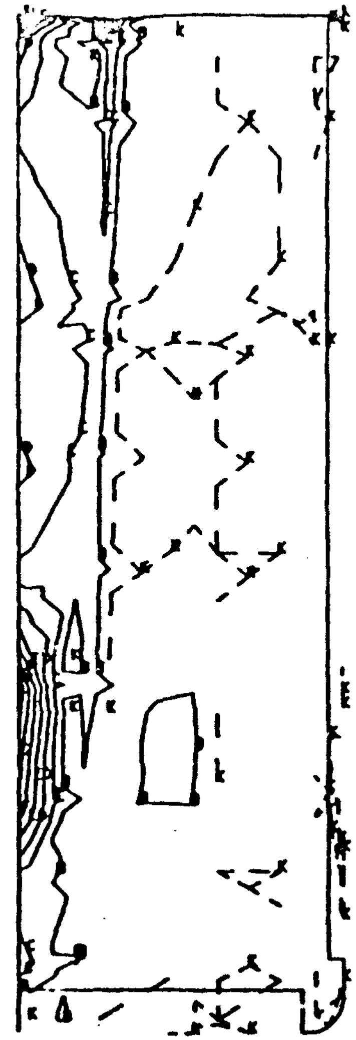
H - -1.684

I = 16.49

J = 1.354

K = 0.000

Figure 29. Shear Stress Contours (Sxy) Of Side Fender, Top Surface, Load Case A1



STRESS CONTOURS (psi)

A = 753.0

B = 3.211

C = 6.498

D = 9.785

E = 13.07

F = 16.35

G = 19.64

H = 22.93

I = 26.22

J = 29.50

K = 0.000

Figure 30. Maximum Principal Stress (S_3) Of Side Fender, Top Surface, Load Case A1

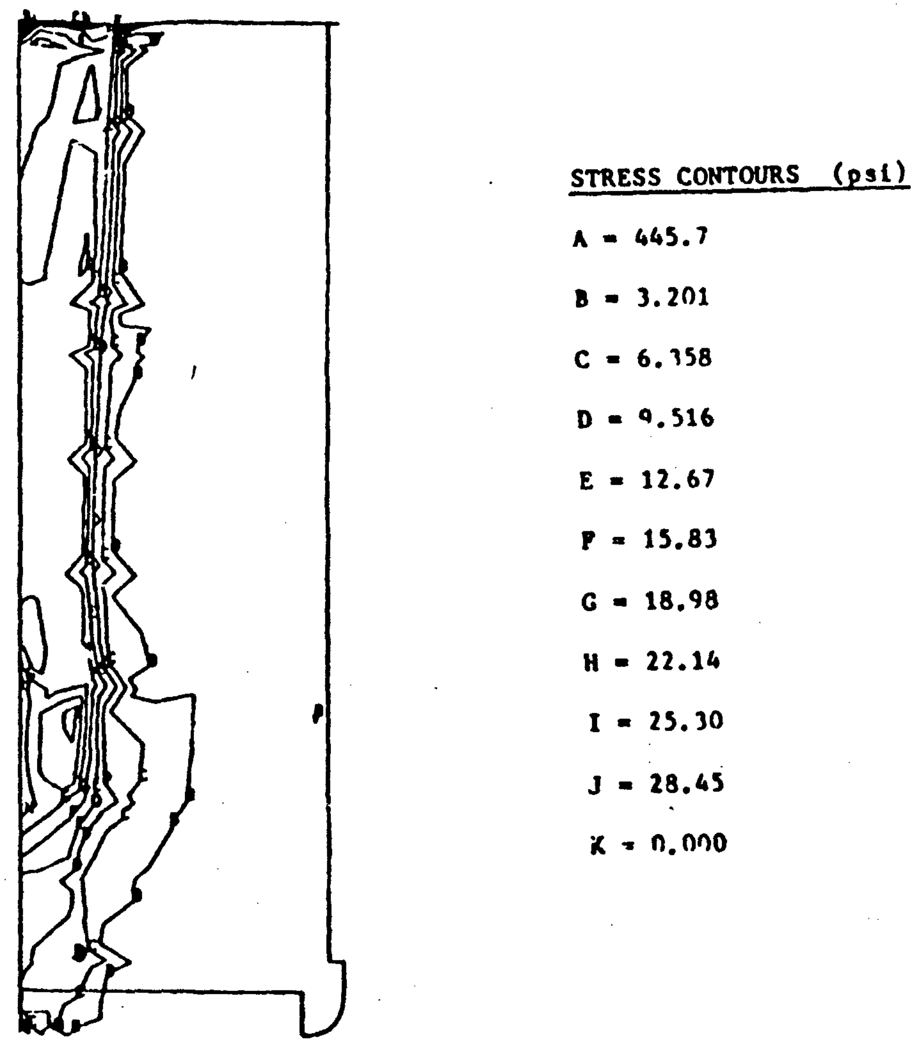


Figure 31. Von Mises Equivalent Stresses (Seq) Of Side Fender, Top Surface, Load Case A1

STRESS CONTOURS (psi)

A = 21.27

B = 16.76

C = 12.25

D = -7.746

E = -3.237

F = 1.271

G = 5.779

H = 10.28

I = 14.79

J = 19.30

K = 0.000

Figure 32. Transverse Stress Contours (Sxx) Of Side Fender, Bottom Surface, Load Case A1

STRESS CONTOURS (psi)

A = 10.98

B = -9.021

C = -7.054

D = -5.086

E = -3.118

F = -1.151

G = 81.64

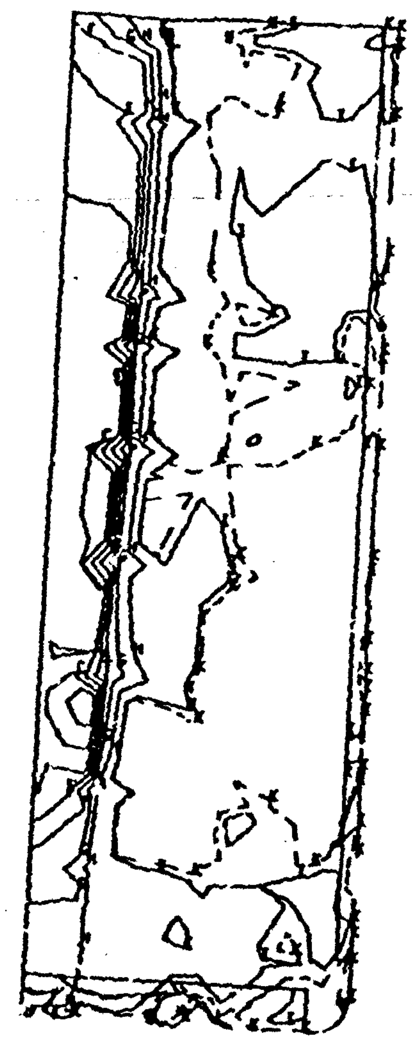
H = 2.784

I = 4.751

J = 6.719

K = 0.000

Figure 33. Longitudinal Stress Contours, (Syy) Of Side Fenders, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = 14.91

B = 13.0

C = 11.22

D = -9.382

E = -7.538

F = -5.649

G = -3.850

H = -2.006

I = 16.29

J = 1.680

K = 0.000

Figure 34. Shear Stress Contours (Sxy) Of Side Fender, Bottom Surface, Load Case A1

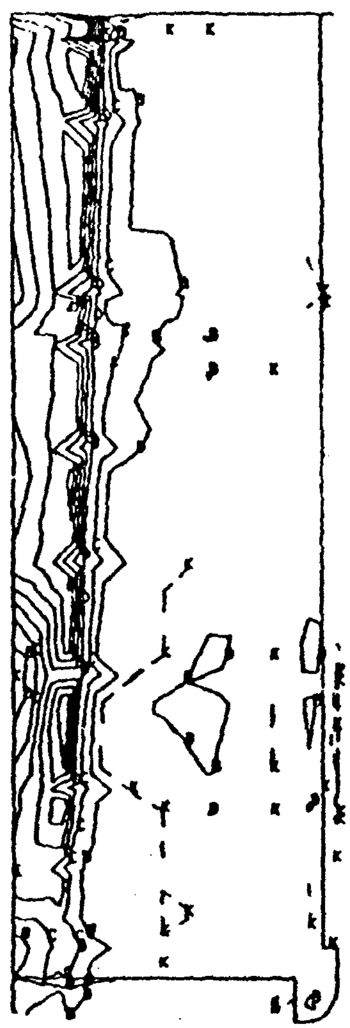
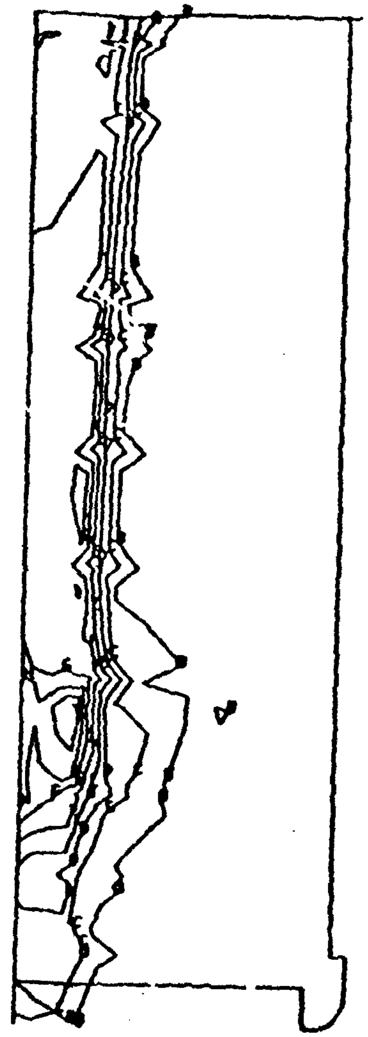


Figure 35. Maximum Principal Stress (S_3) Of Side Fender, Bottom Surface, Load Case A1



STRESS CONTOURS (psi)

A = 671.0

B = 3.474

C = 6.882

D = 10.29

E = 13.69

F = 17.10

G = 20.51

H = 23.92

I = 27.32

J = 30.73

K = 0.000

Figure 36. Von Mises Equivalent Stresses (Seq) Of Side Fender, Bottom Surface, Load Case Al

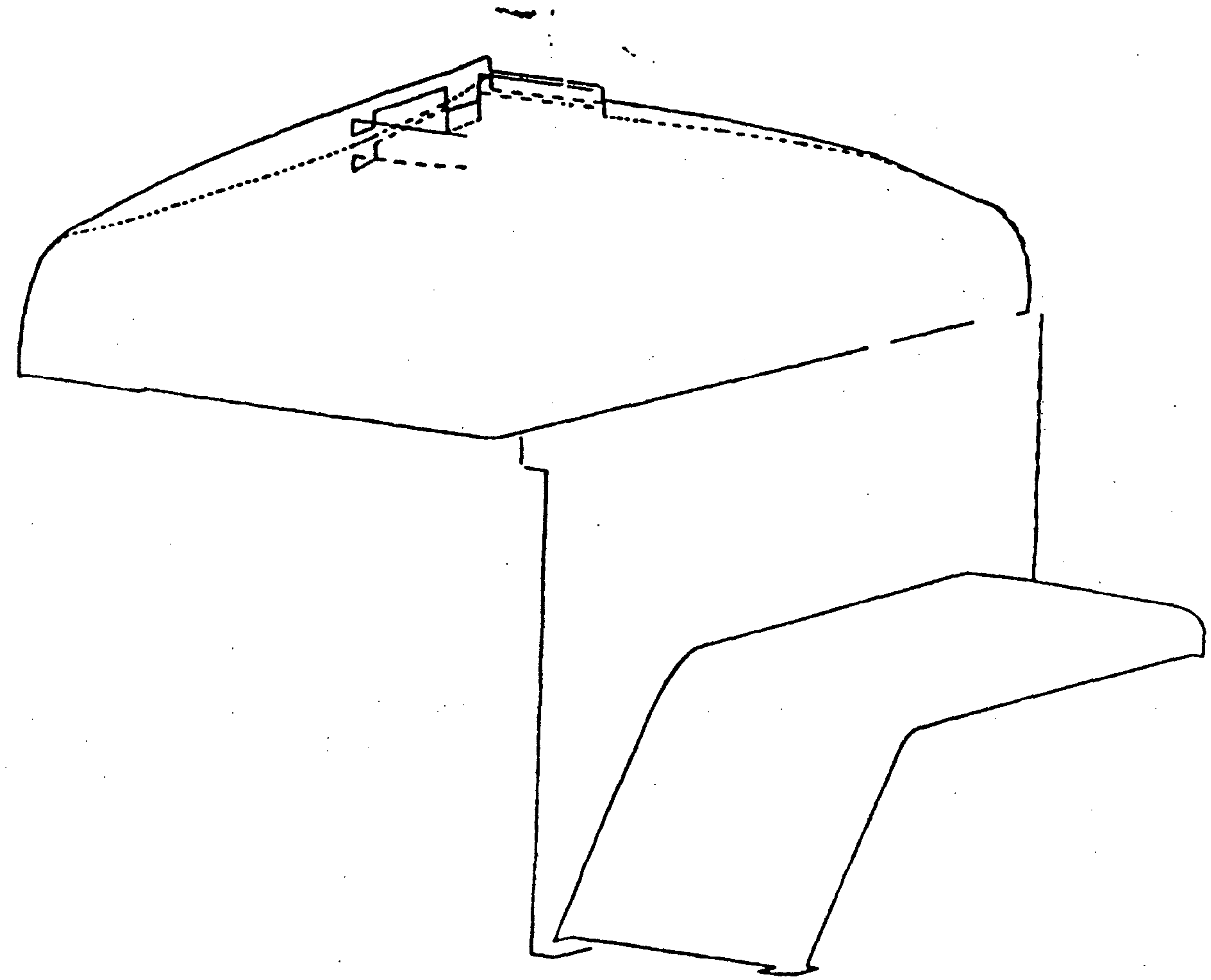


Figure 37. Deformed Hood Assembly Due To A Uniformly Distributed Load Of 1,000 Pounds On Top Surface Of Hood

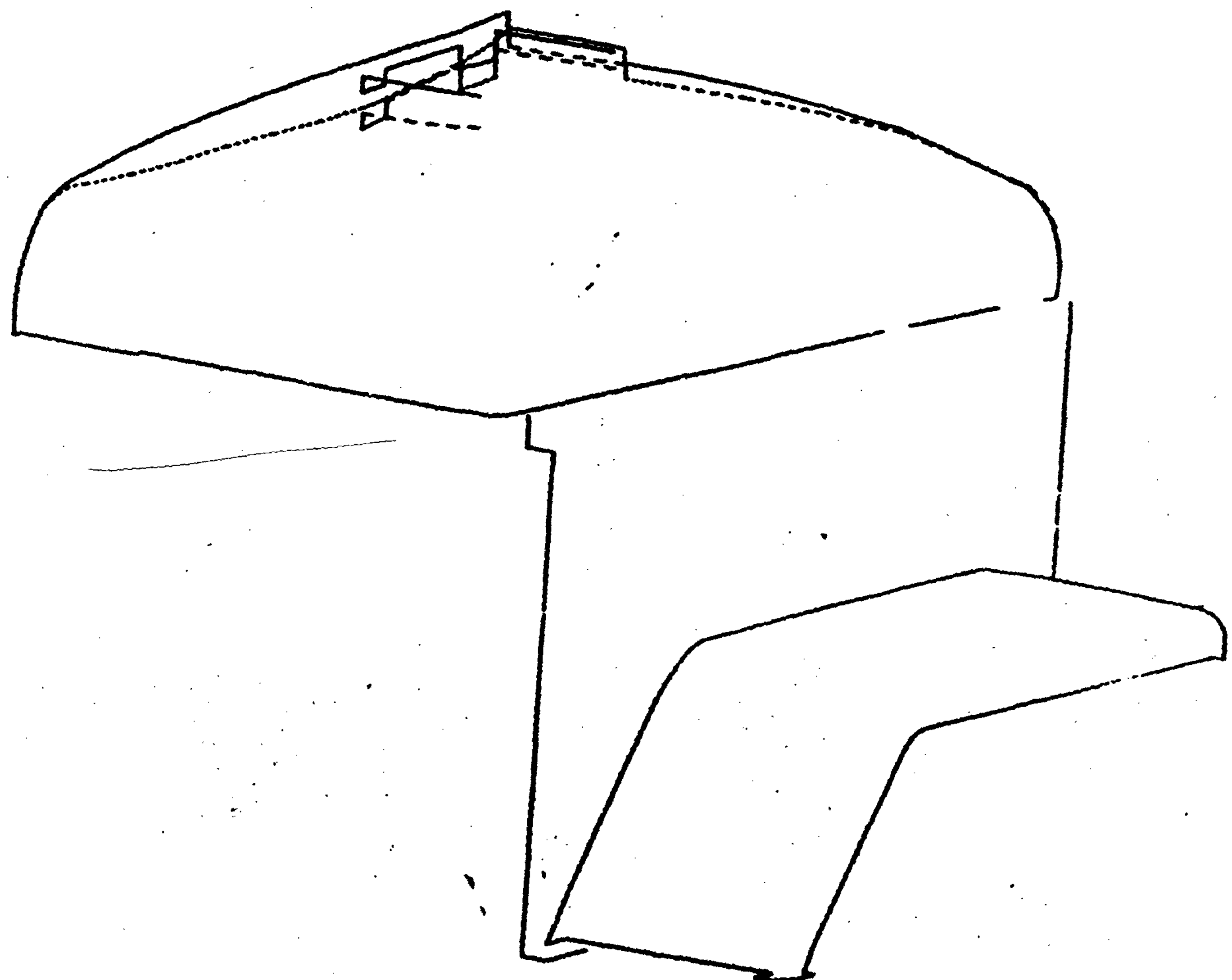
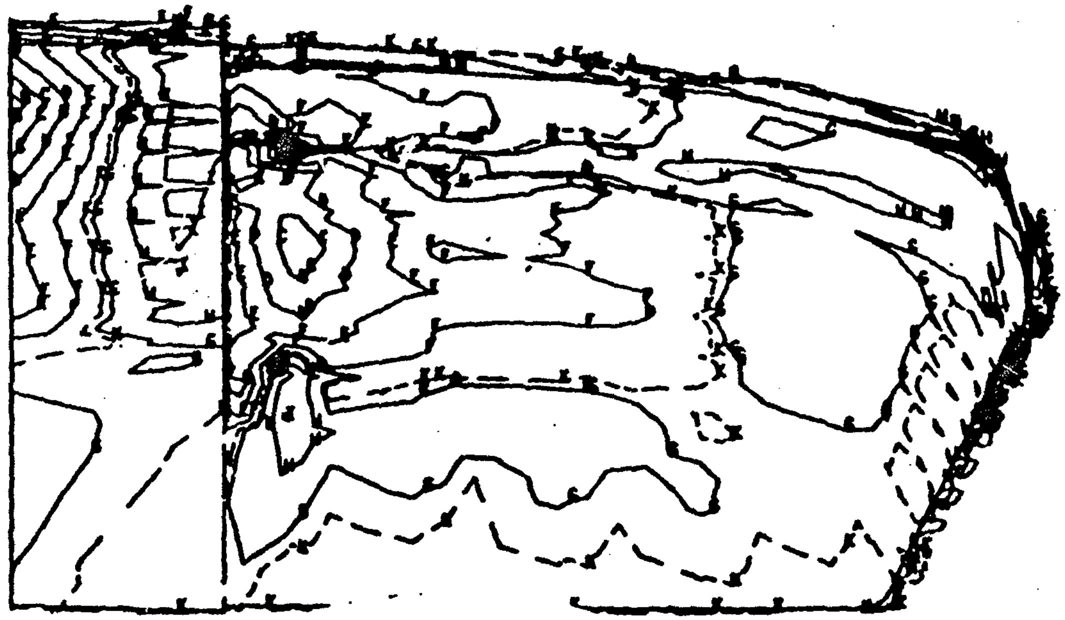


Figure 38. Deformed Hood Due To Load Case B1



STRESS CONTOURS (psi)

A = -3,990

B = -3,292

C = -2,593

D = -1,895

E = -1,196

F = -498

G = 200

H = 898

I = 1,597

J = 2,295

K = 0.000

Figure 39. Transverse Stresses (Sxx), Top Surface Of Truck Hood, Outer Panel, Load Case B1

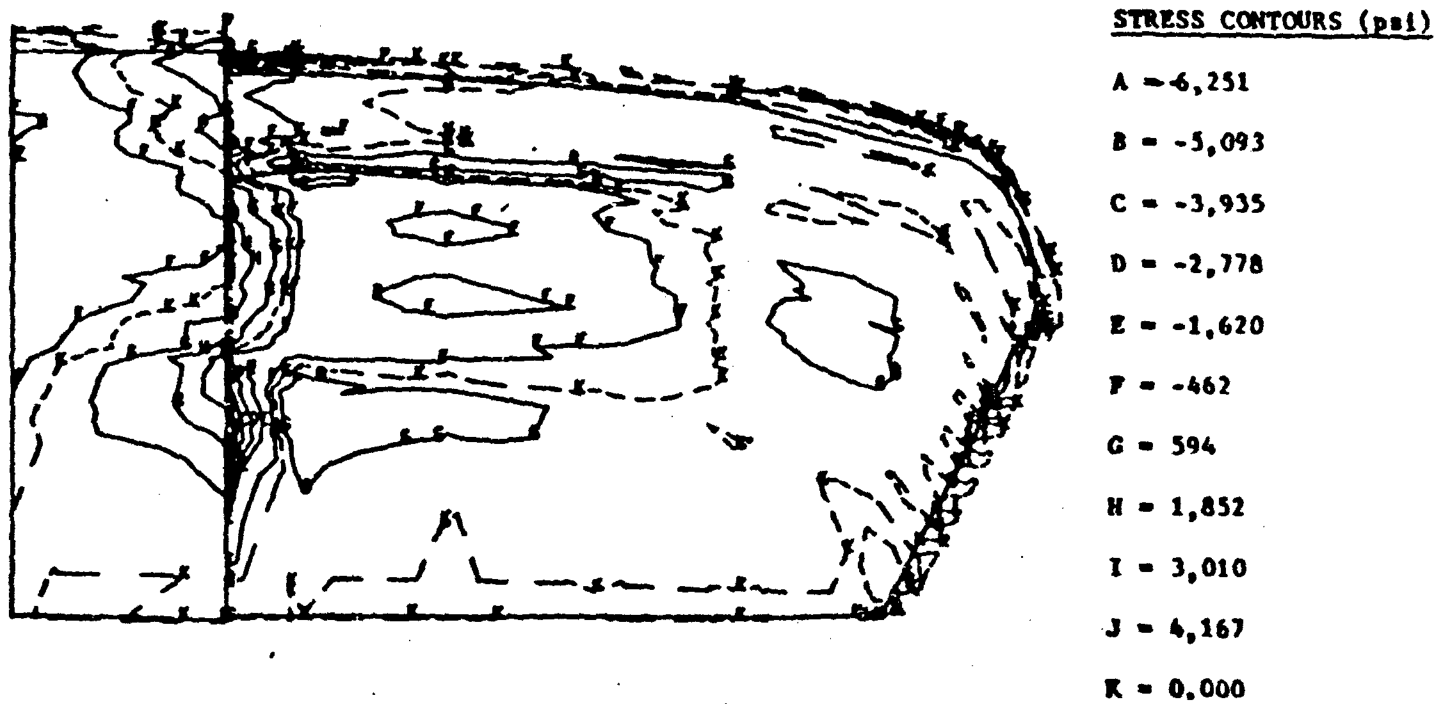


Figure 40. Longitudinal Stresses (Syy), Top Surface Of Truck Hood, Load Case B1

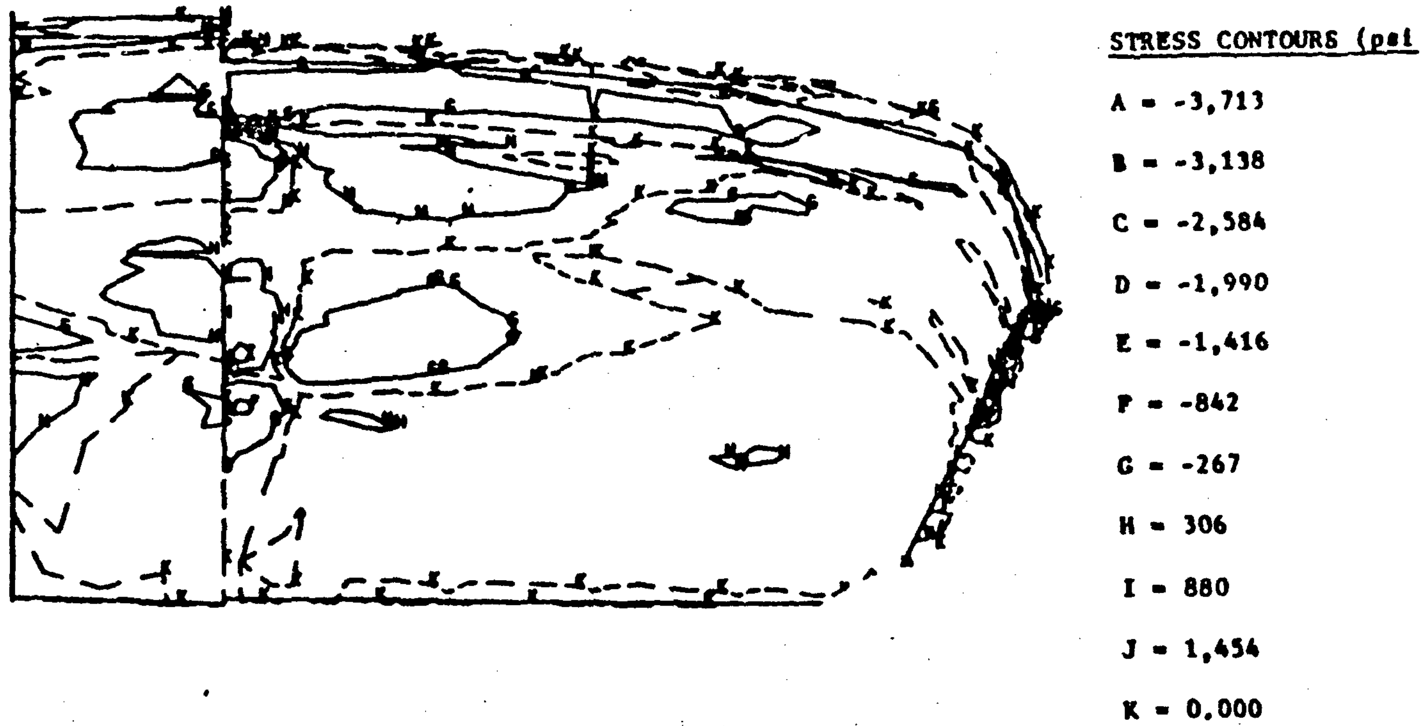


Figure 41. Shear Stresses (Sxy), Top Surface Of Truck Hood, Load Case B1

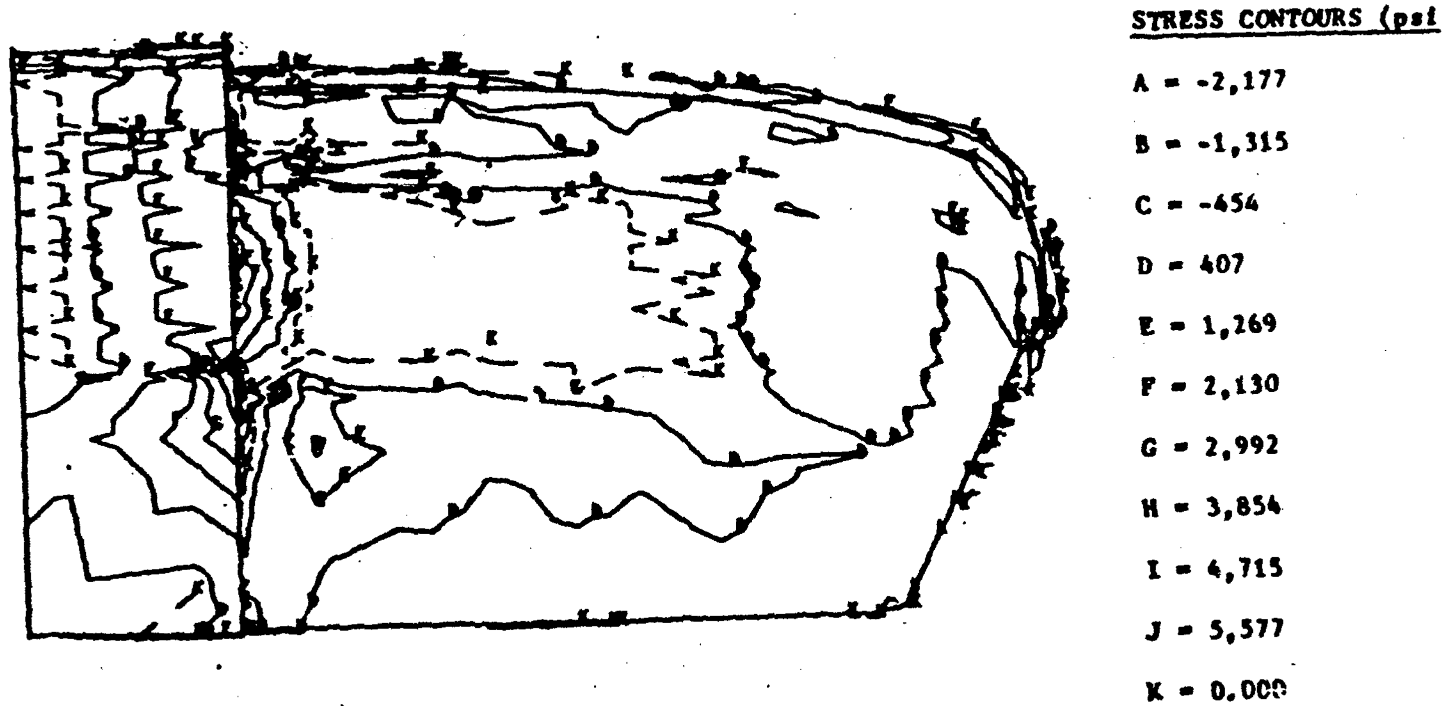


Figure 42 Maximum Principal Stresses (S_2). Top Surface Of Truck Hood, Load Case

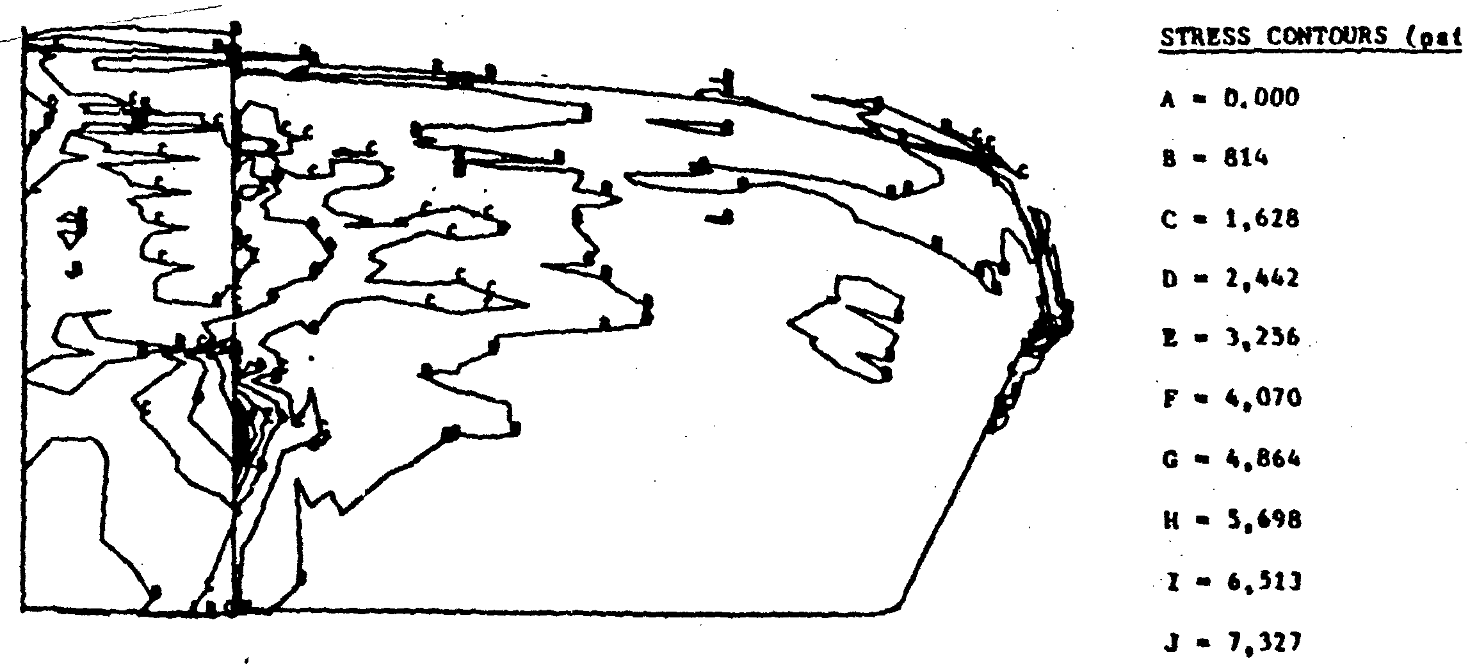
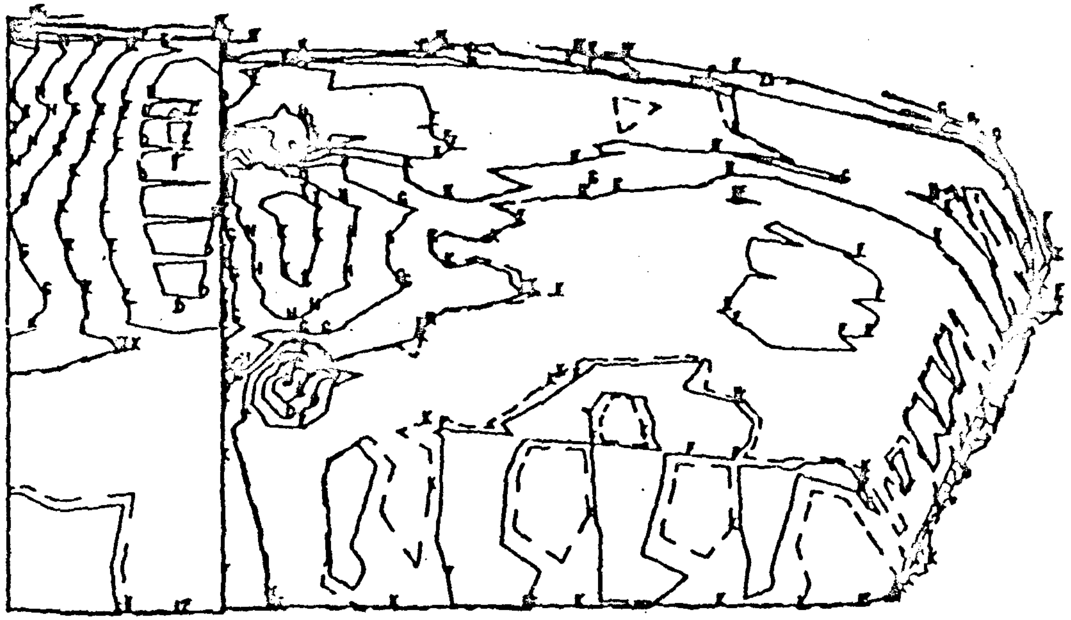


Figure 43. Von Mises Equivalent Stresses (Seq), Top Surface Of Trunk Hood, Load Case B1



STRESS CONTOURS (psi)

A = -3,850

B = -3,873

C = -2,295

D = -1,518

E = -741

F = 360

G = 813

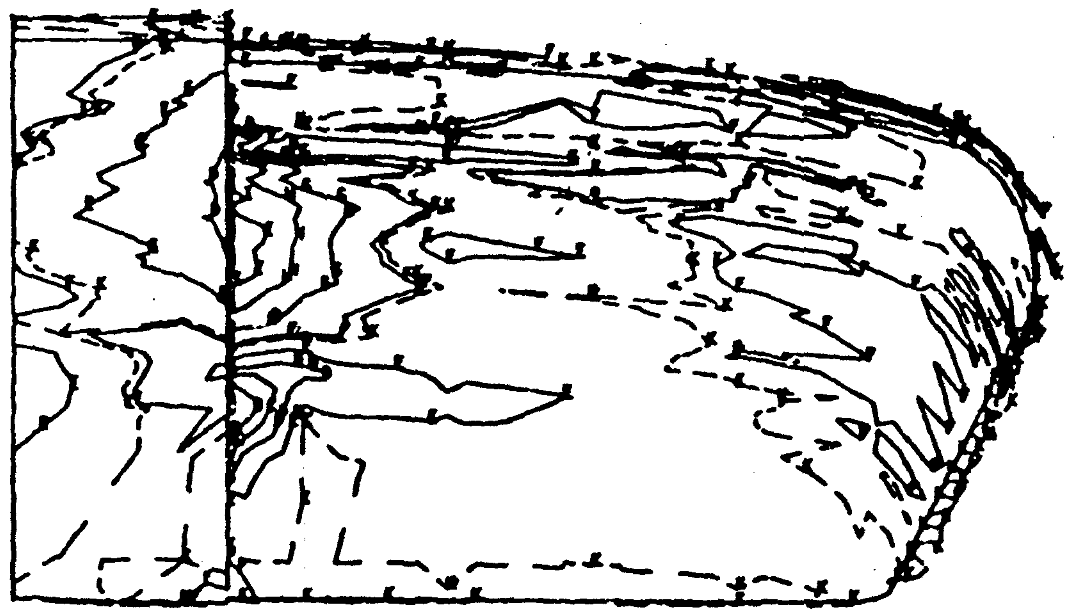
H = 1,590

I = 2,367

J = 3,145

K = 0,000

Figure 44. Transverse Stresses (Sxx), Bottom Surface of Truck Hood, Load Case B1



STRESS CONTOURS (psi)

A = -4,800

B = -3,805

C = -2,810

D = -1,814

E = -819

F = 176

G = 117

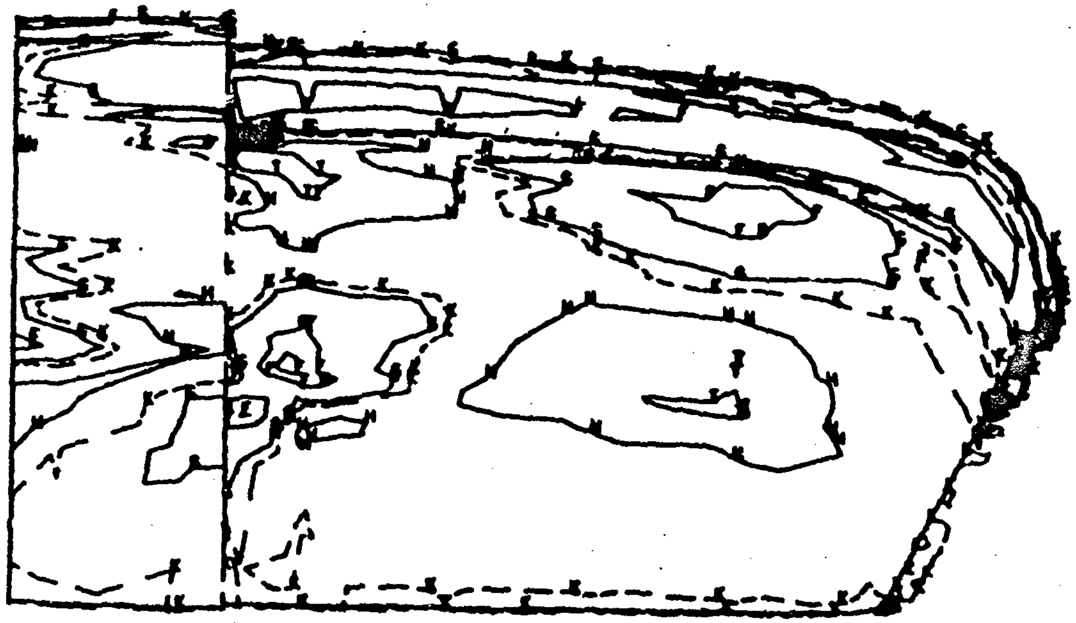
H = 2,166

I = 3,162

J = 4,157

K = 0.000

Figure 45. Longitudinal Stresses (Syy), Bottom Surface Of Truck Hood, Load Case B1



STRESS CONTOURS (psi)

A = -2,550

B = -2,142

C = -1,735

D = -1,328

E = -920

F = -513

G = -105

H = 301

I = 708

J = 1,116

K = 0,000

Figure 46. Shear Stresses (Sxy), Bottom Surface Of Truck Hood, Load Case B1

Figure 47. Maximum Principal Stresses (S_3)Bottom Surface Of Truck Hood, Load Case B1

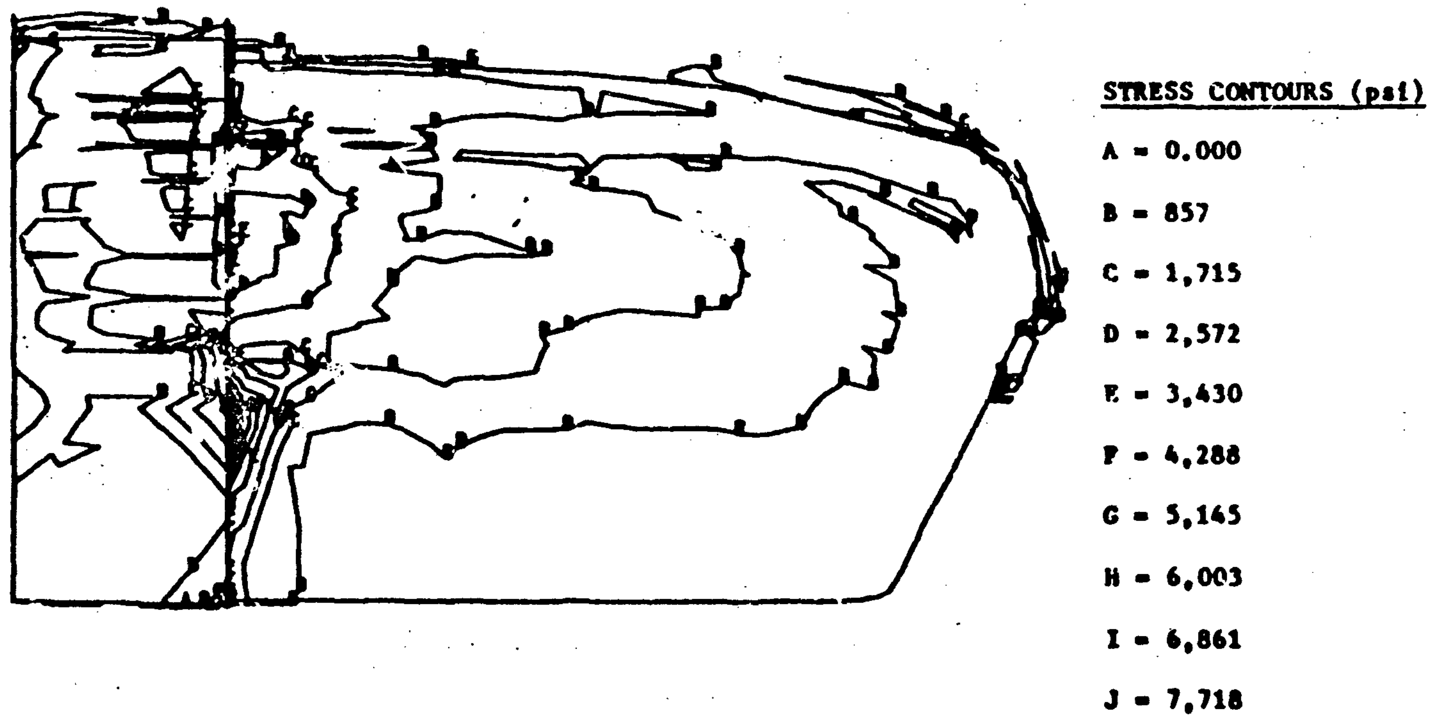


Figure 48. Von Mises Equivalent Stresses (Seq), Bottom Surface Of Truck Hood, Load Case B1

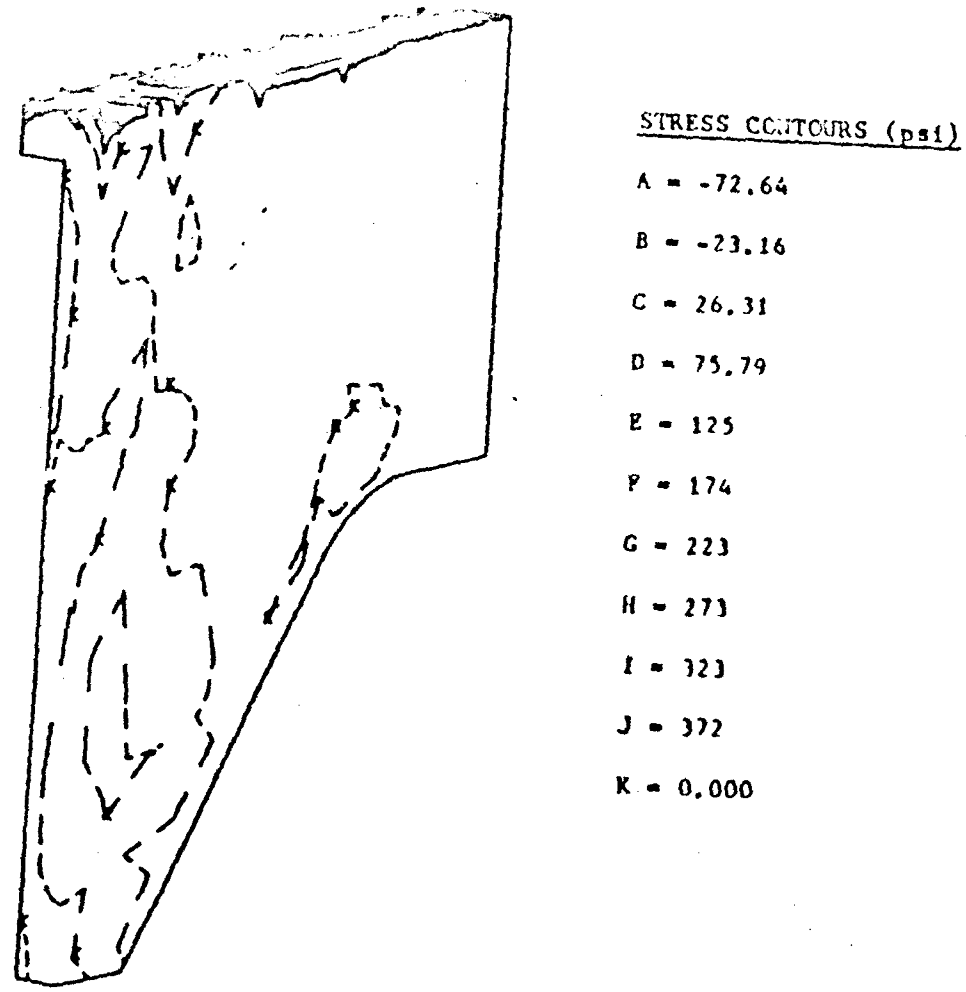


Figure 49. Transverse Stress Contours (Sxx), Of Side Fender, Top Surface, Load Case B1

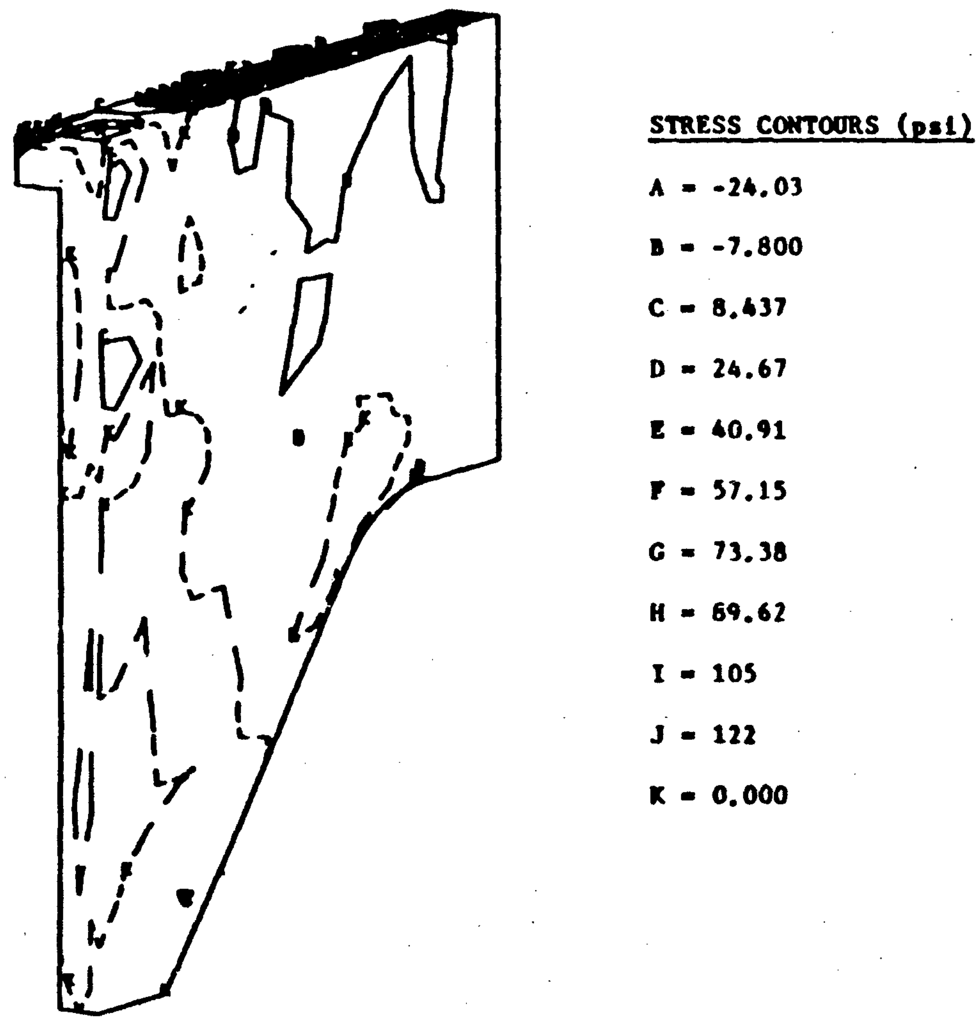


Figure 50. Longitudinal Stress Contours (Syy),Of Side Fender, Top Surface, Load Case B1

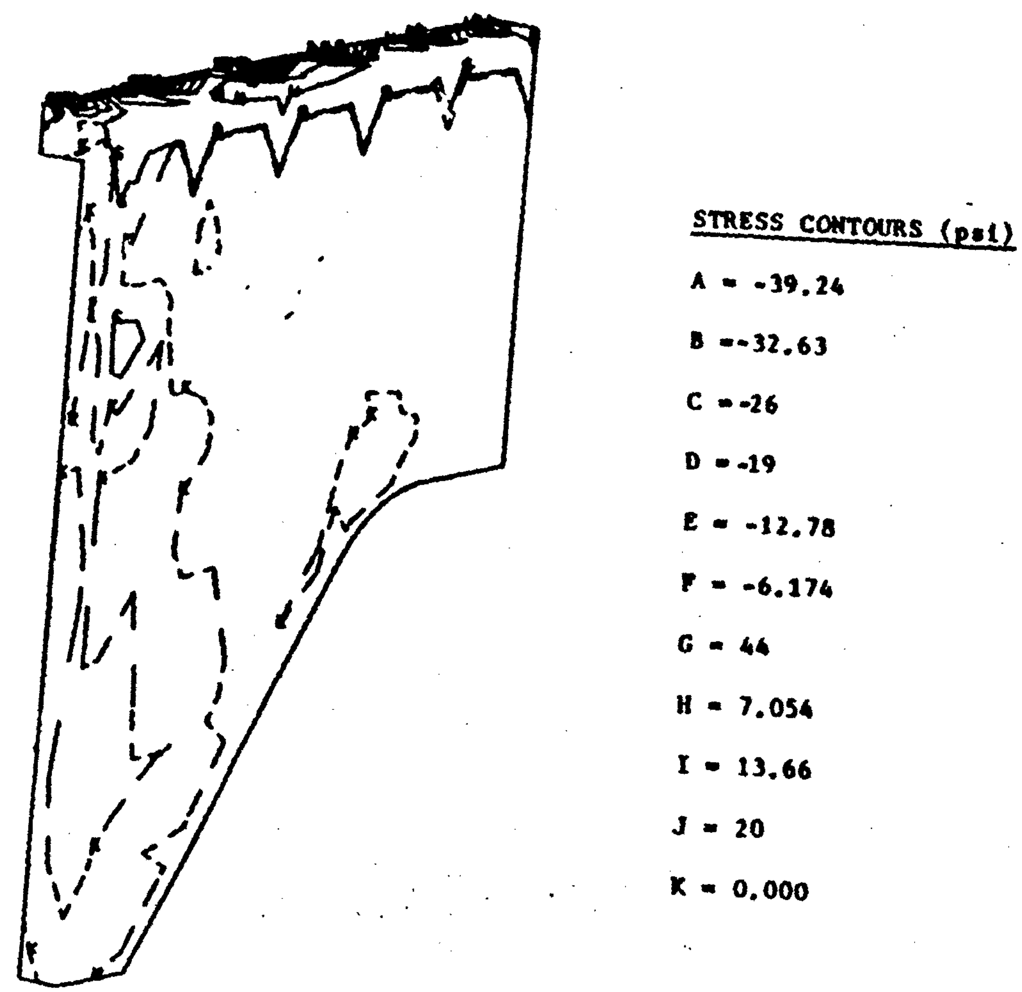
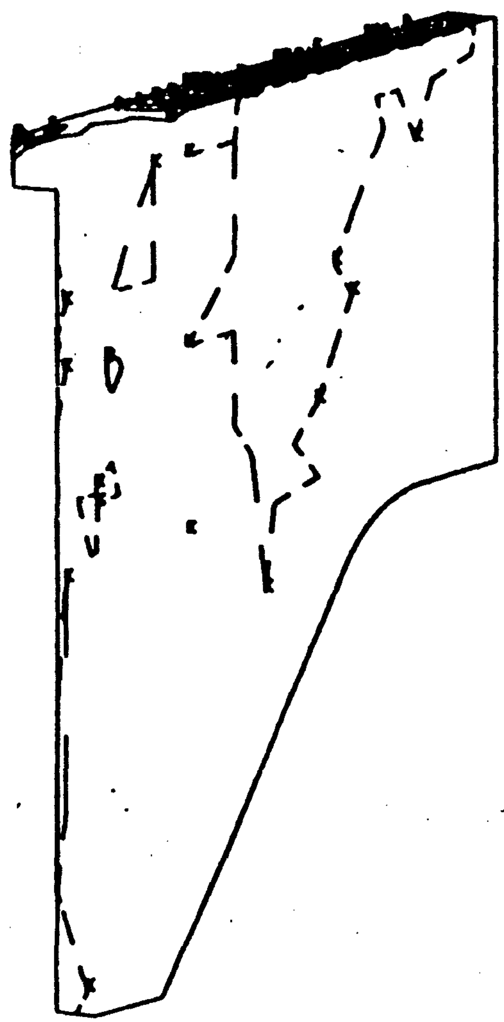


Figure 51. Shear Stress Contours (Sxy) Of Side Fender, Top Surface, Load Case B1



STRESS CONTOURS (psi)

A = -10

B = 32.92

C = 75.93

D = 118.9

E = 161.9

F = 204.9

G = 247.9

H = 290.9

I = 333.9

J = 376.9

K = 0.000

Figure 52. Maximum Principal Stresses (S_3) Of Side Fender, Top Surface, Load Case B1

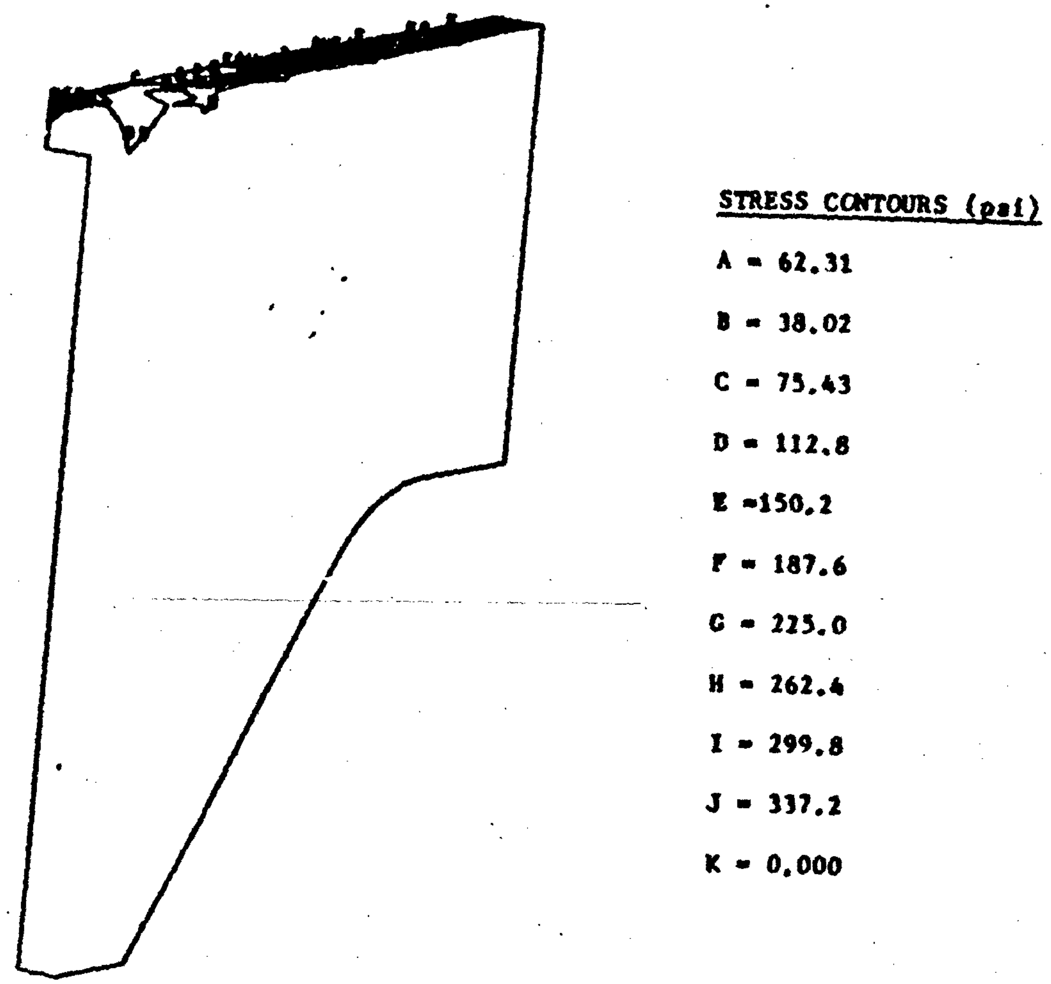
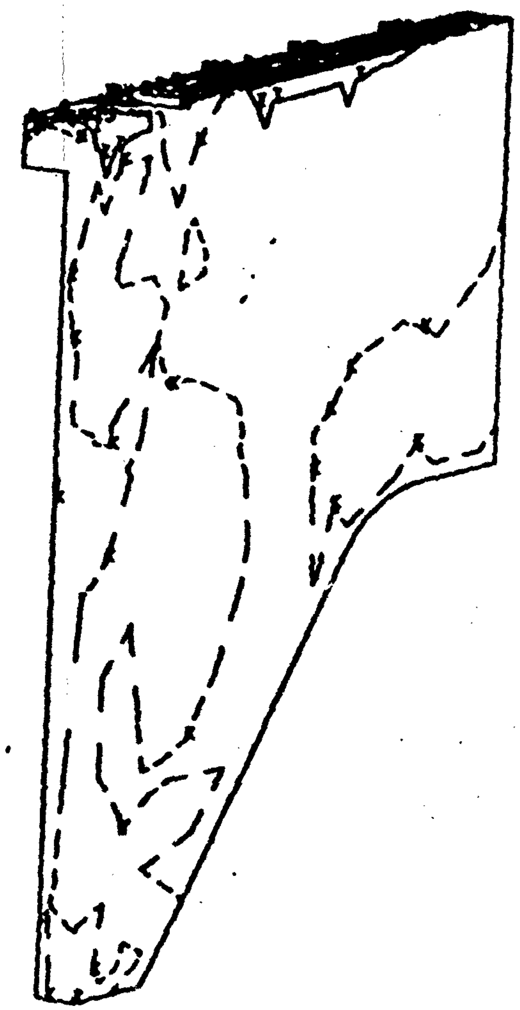


Figure 53. Von Mises Equivalent Stresses (Seq) Of Side Fender, Top Surface, Load Case B1



STRESS CONTOURS (psi)

A = -367.8

B = -319.5

C = -271.2

D = -222.9

E = -174.7

F = -126.4

G = -781.6

H = -29.89

I = 18.38

J = 66.65

K = 0.000

Figure 54. Transverse Stress Contours (Sxx) Of Side Fender, Bottom Surface, Load Case B1

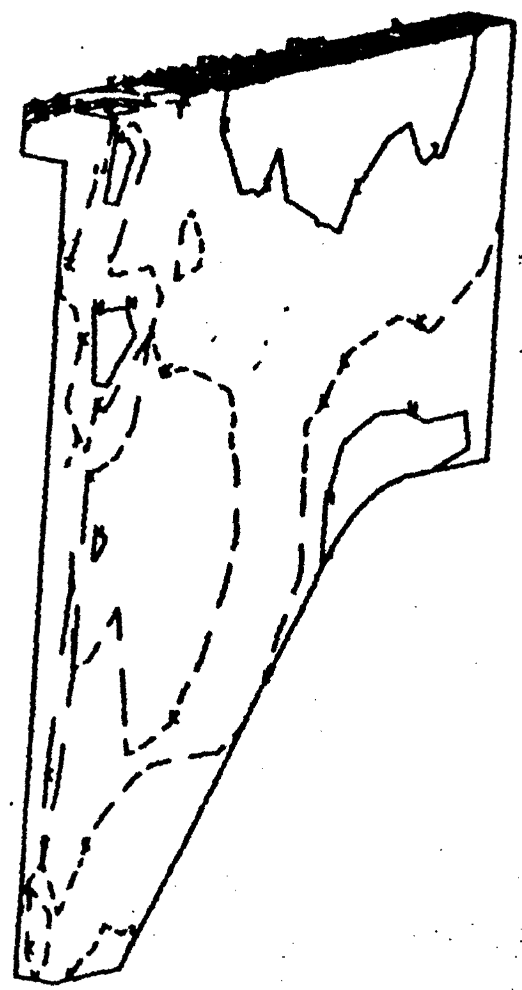
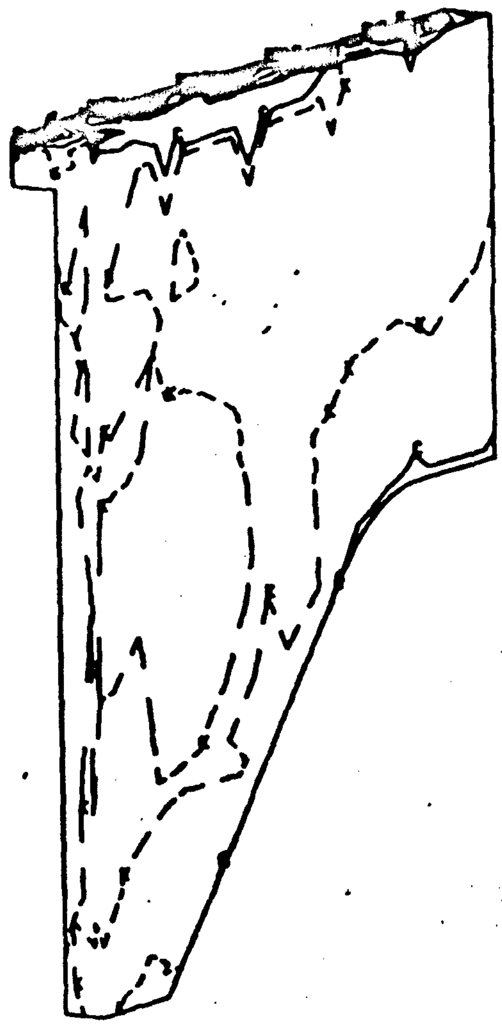


Figure 55. Longitudinal Stress Contours (Syy) Of Side Fender, Bottom Surface, Load Case B1



STRESS CONTOURS (psi)

A = -14.69

B = -8.181

C = -1.665

D = 4.850

E = 11.36

F = 1.788

G = 2.439

H = 30.91

I = 37.43

J = 43.94

K = 0.000

Figure 56. Shear Stress Contours (Sxy) Of Side Fender, Bottom Surface, Load Case B1

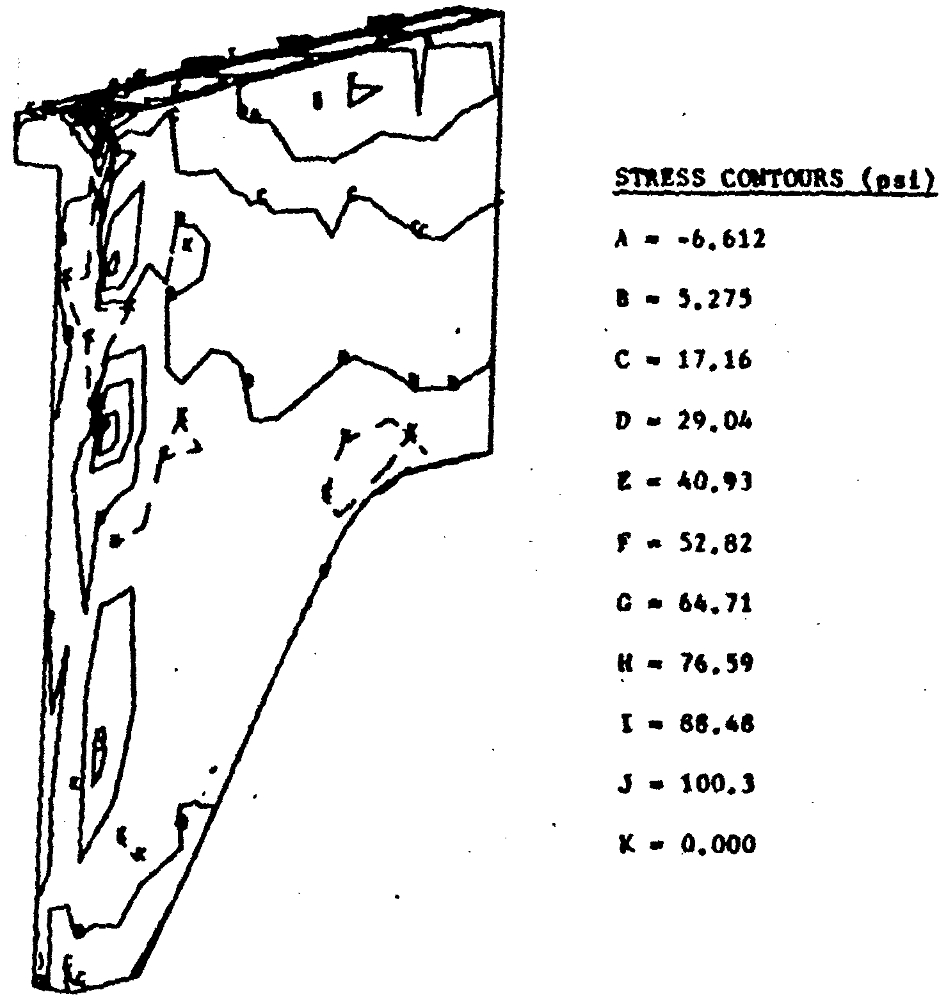


Figure 57. Maximum Principal Stresses (S_3), Of Side Fender, Bottom Surface, Load Case B1

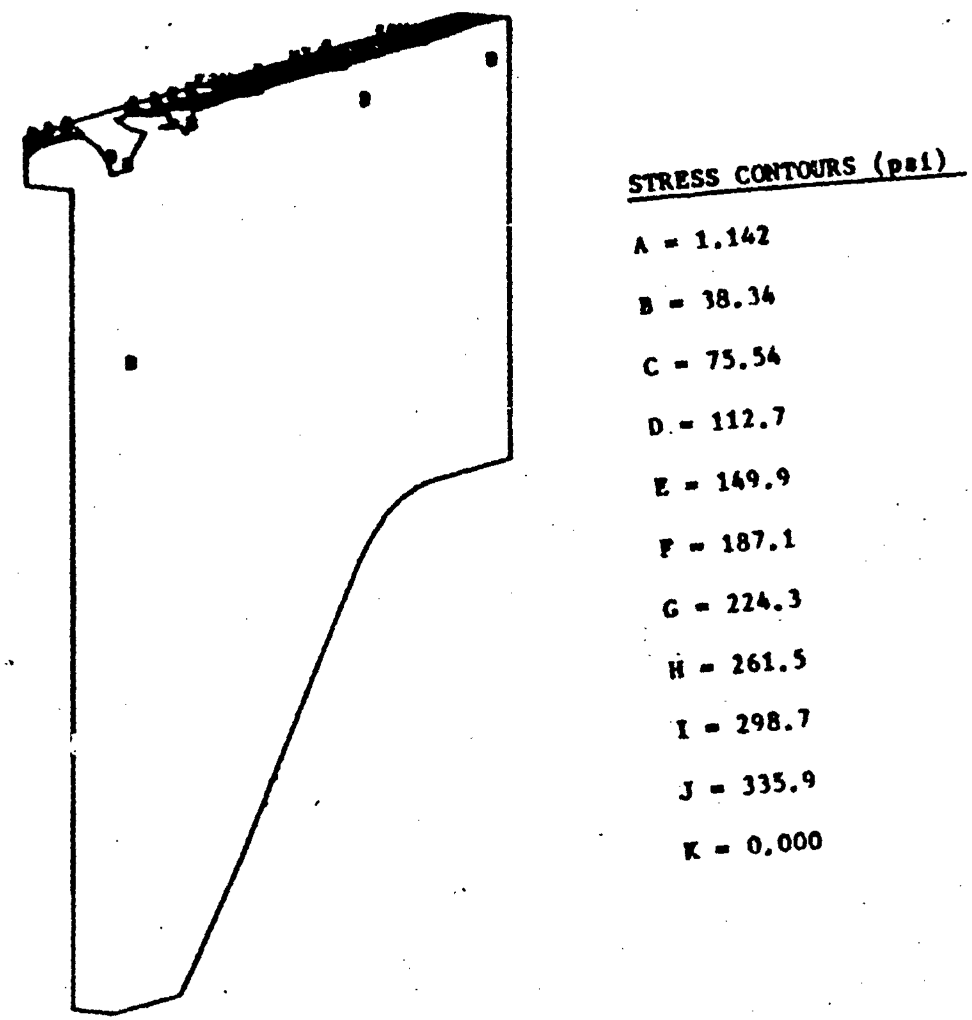


Figure 58. Von Mises Equivalent Stresses (Seq), Of Side Panel, Bottom Surface, Load Case B1

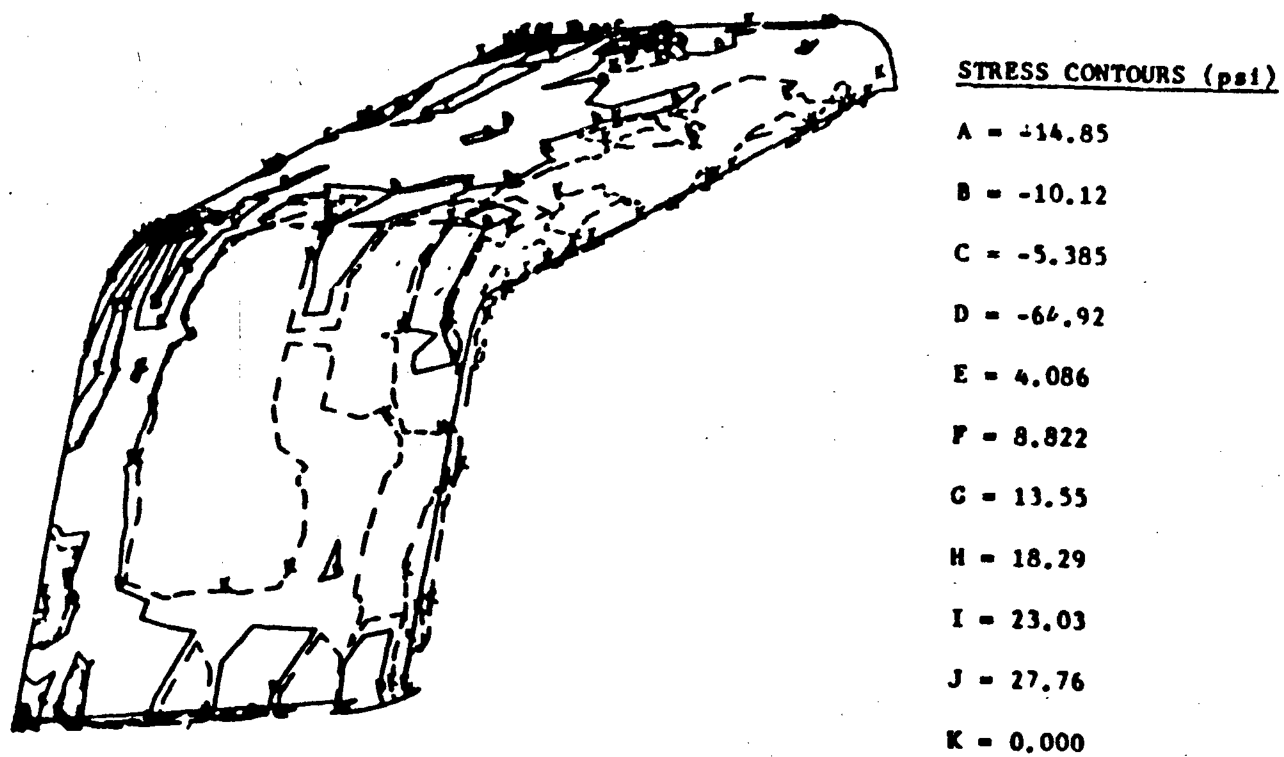
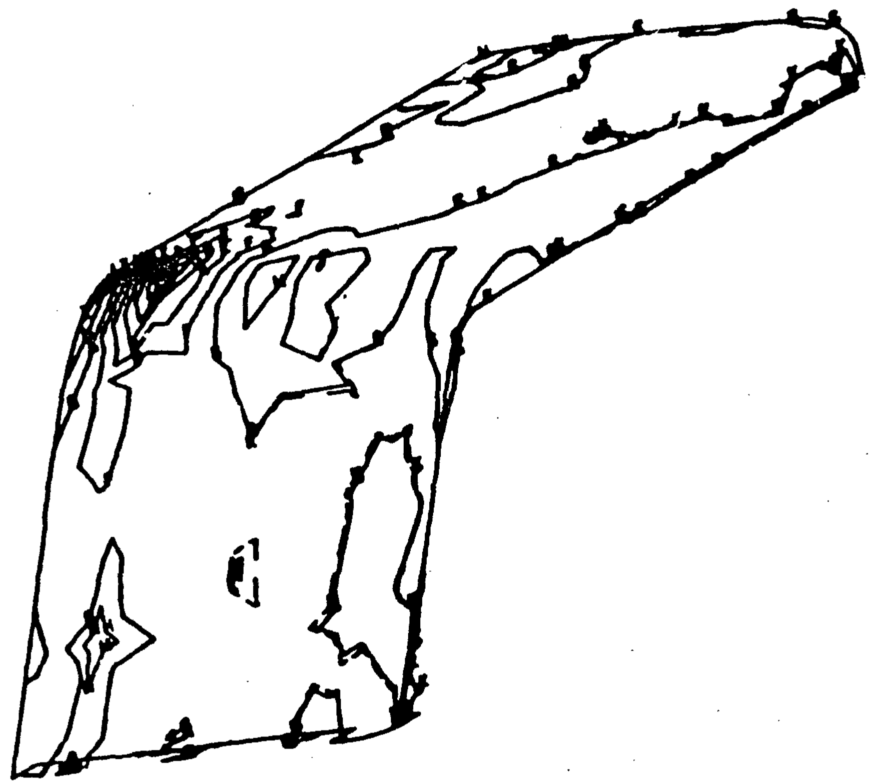


Figure 59. Transverse Stress Contours (Sxx), Of Fender Panel, Top Surface, Load Case B1



STRESS CONTOURS (psi)

A = -14.71

B = -12.25

C = -9.799

D = -7.342

E = -4.886

F = -2.430

G = 262.5

H = 2.482

I = 4.938

J = 7.395

K = 0.000

Figure 60. Longitudinal Stress Contours (Syy), Of Fender Panel, Top Surface, Load Case B1

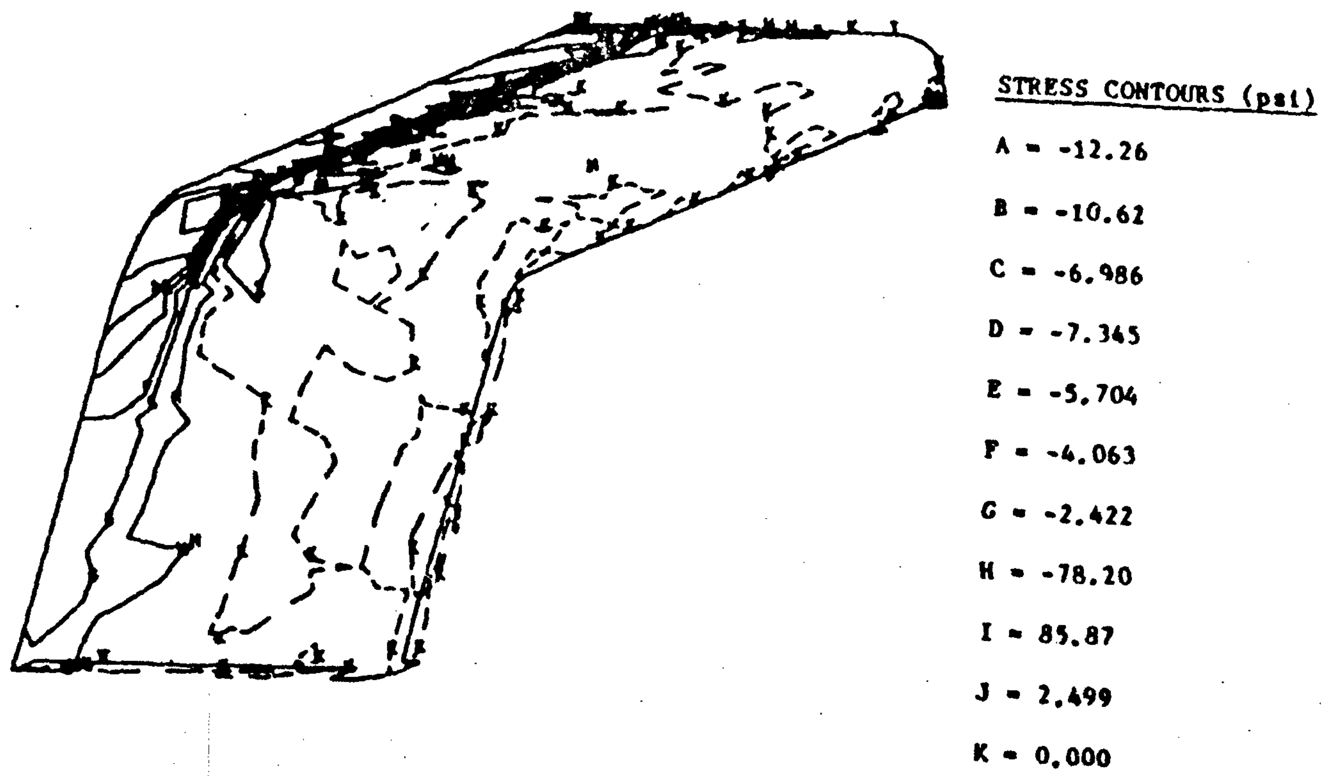


Figure 61. Shear Stress Contours (Sxy), Of Side Fender Panel, Top Surface, Load Case B1

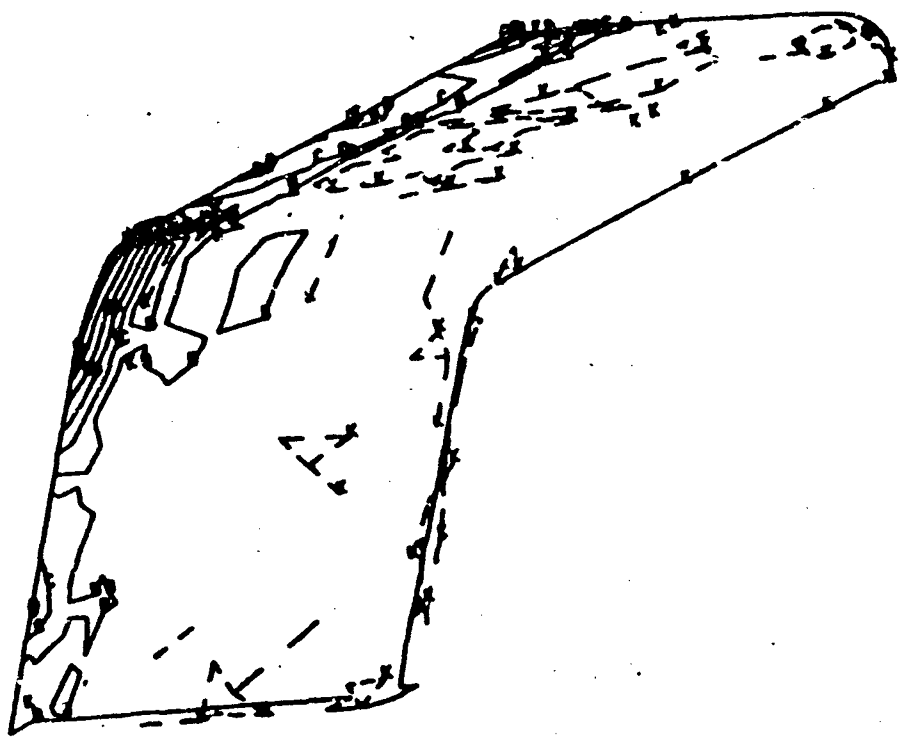


Figure 62. Maximum Principal Stresses (S_3), Of Side Fender Panel, Top Surface, Load Case B1

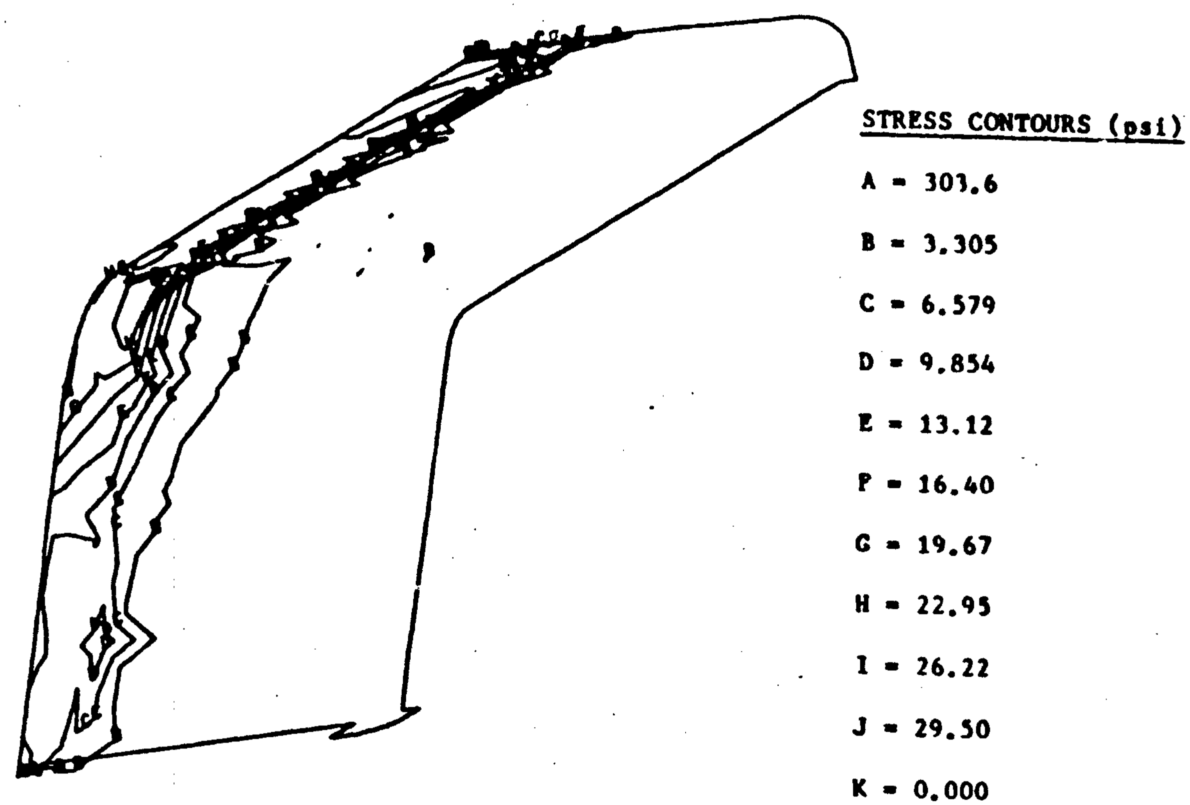
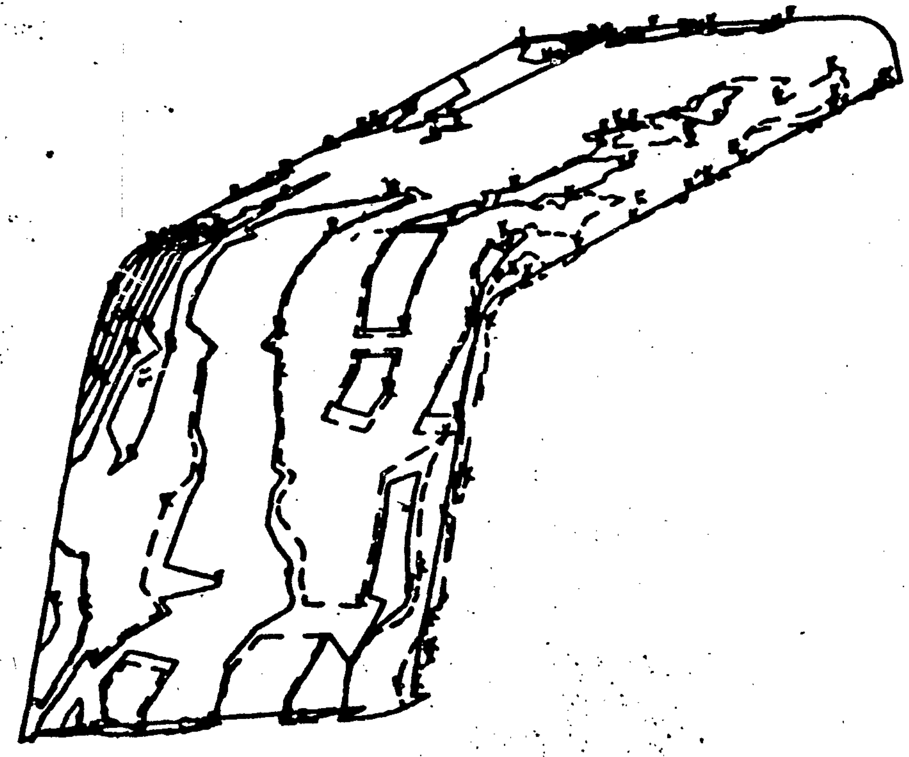


Figure 63. Von Mises Equivalent Stresses (Seq), Of Side Fender Panel, Top Surface, Load Case B1



STRESS CONTOURS (psi)

A = -21.97

B = -17.62

C = -13.26

D = -8.936

E = -4.593

F = -24.83

G = 4.096

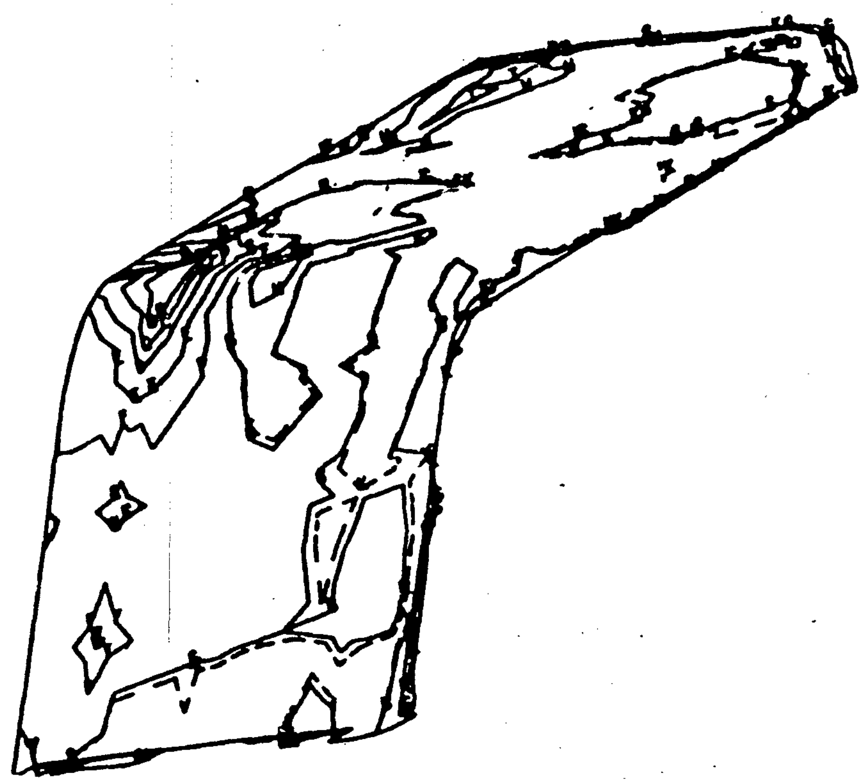
H = 8.442

I = 12.78

J = 17.13

K = 0.000

Figure 64. Transverse Stress Contours (Sxx), Of Side Fender Panel, Bottom Surface, Load Case B1



STRESS CONTOURS (psi)

A = -11.21

B = -9.357

C = -7.497

D = -5.638

E = -3.778

F = -1.919

G = -.596

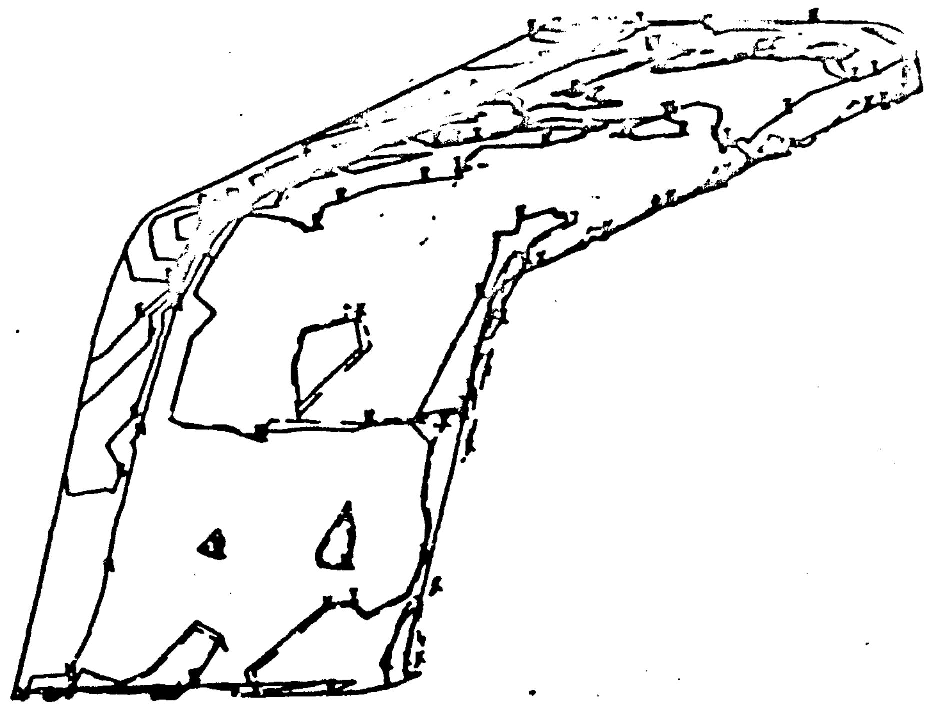
H = 1.799

I = 3.659

J = 5.518

K = 0.000

Figure 65. Longitudinal Stress Contours (Syy),Of Side Fender, Bottom Surface, Load Case B1



STRESS CONTOURS (psi)

A = -14.63

B = -12.61

C = -10.98

D = -9.162

E = -7.336

F = -5.510

G = -3.684

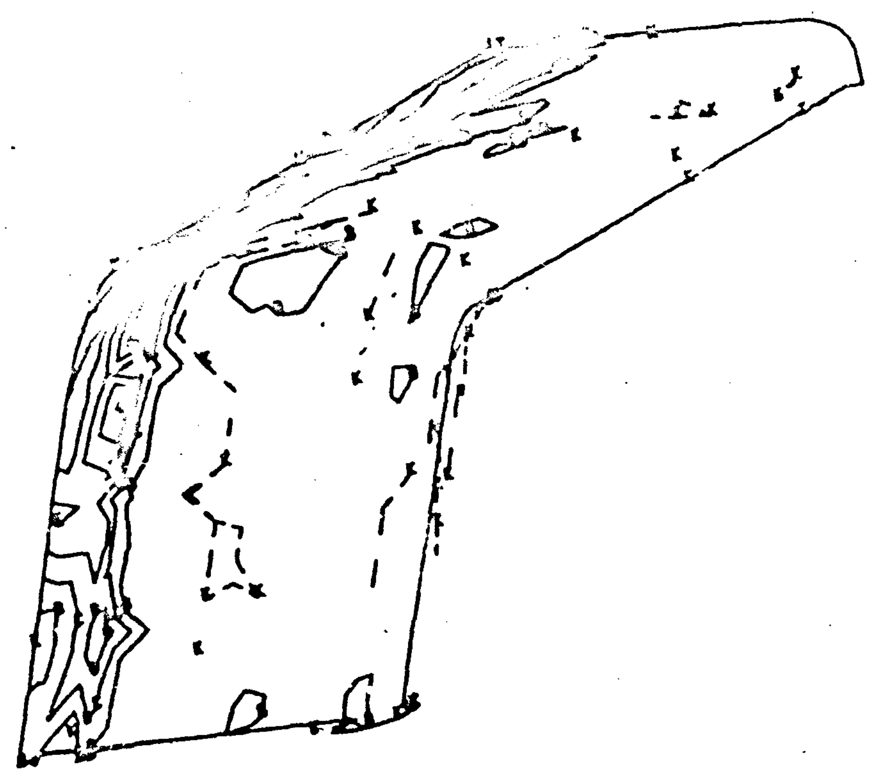
H = -1.859

I = -332.1

J = 1.792

K = 0.000

Figure 66. Shear Stress Contours (Sxy), Of Side Fender Panel, Bottom Surface, Load Case B1



STRESS CONTOURS (psi)

A = -19.25

B = 1.870

C = 3.934

D = 5.997

E = 6.960

F = 10.12

G = 12.18

H = 14.25

I = 16.31

J = 18.37

K = 0.000

Figure C7. Maximum Principal Stress (S_3), Of Side Fender, Bottom Surface, Load Case B1

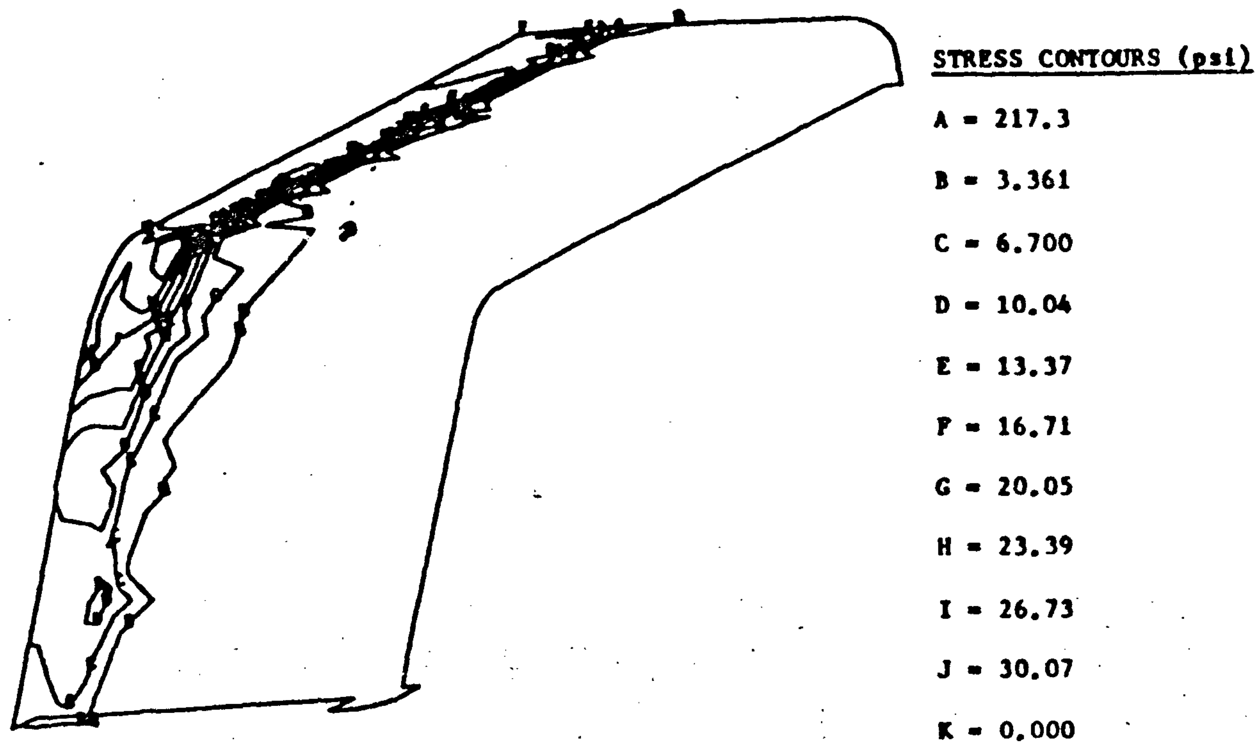


Figure 68. Von Mises Equivalent Stresses (Seq), Of Side Fender, Bottom Surface, Load Case B1

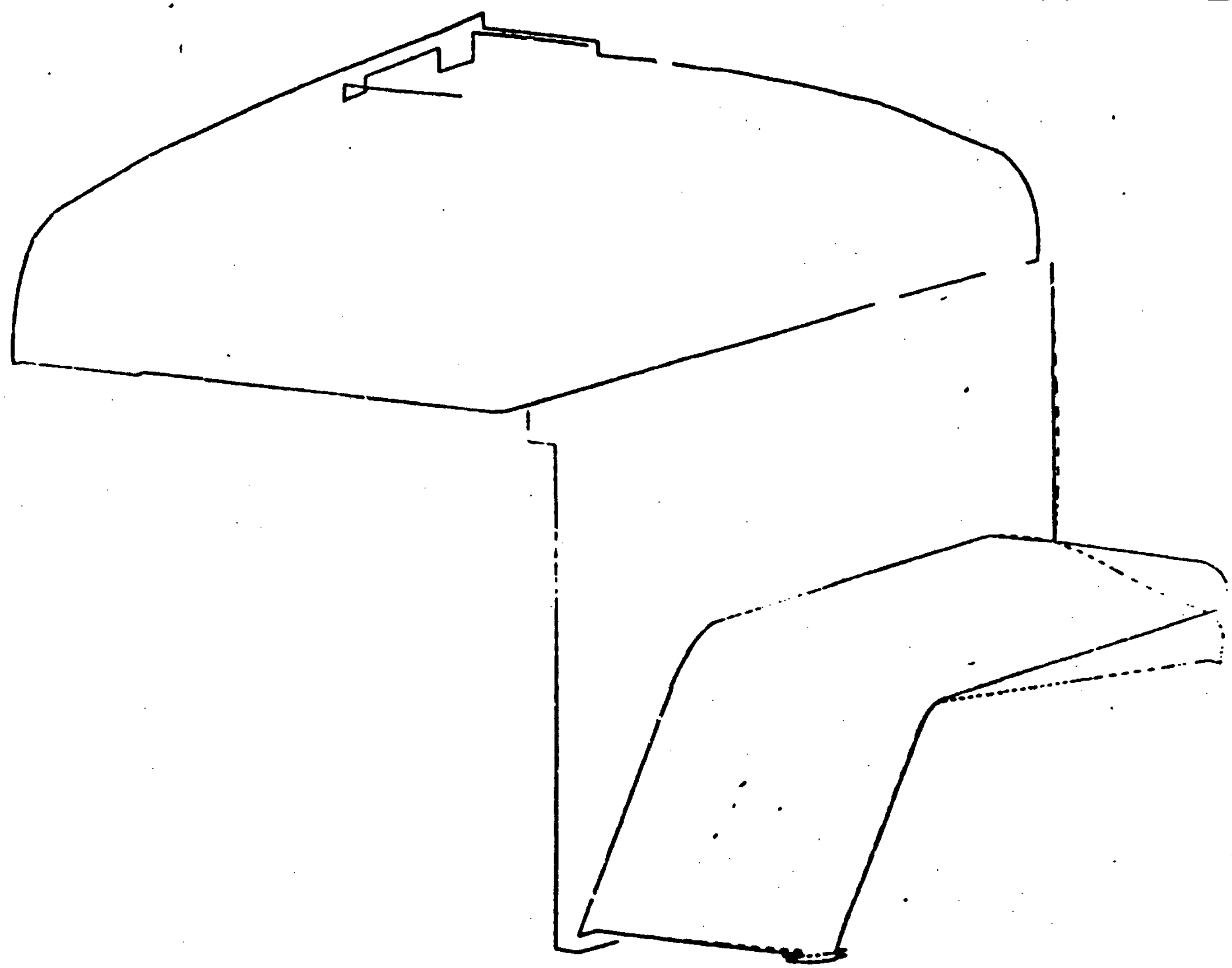


Figure 69. Deformed Hood Due To Load Case B2

STRESS CONTOURS (psi)

A = -762.8

B -531.5

C = -300.2

D = -689.7

E = 162.3

F = 393.6

G = 624.9

H = 856.2

I = 1,087

J = 1,318

K = 0.000

Figure 70. Transverse Stresses (Sxx), Top Surface Of Truck Hood, Load Case B2

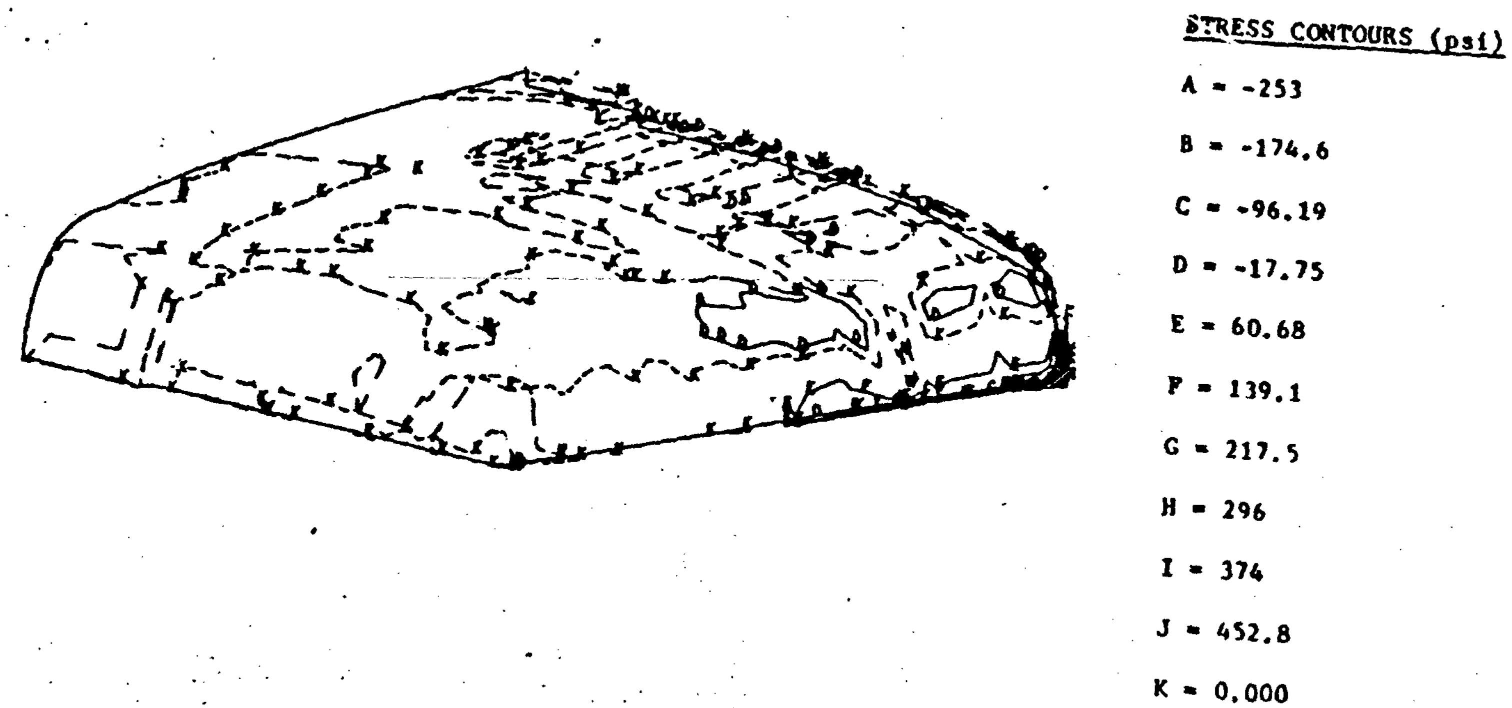


Figure 71. Longitudinal Stresses (Syy), Top Surface Of Truck Hood, Load Case B2

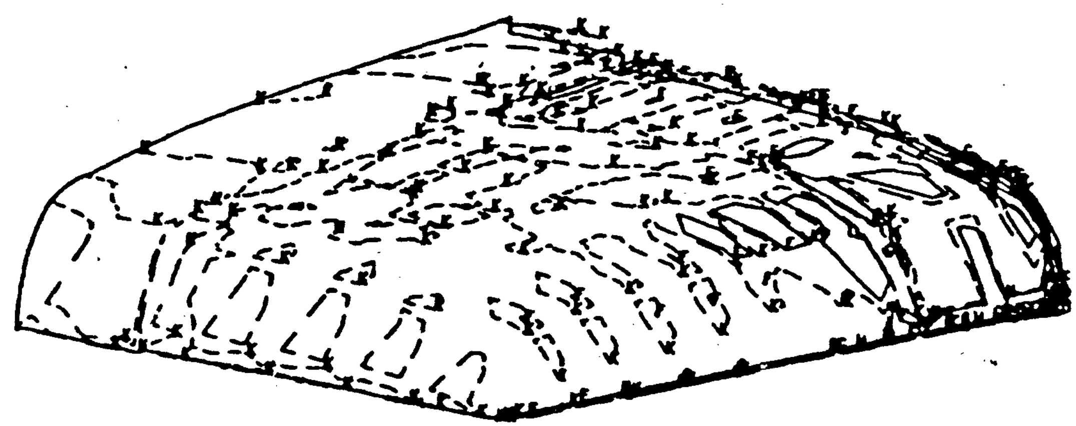
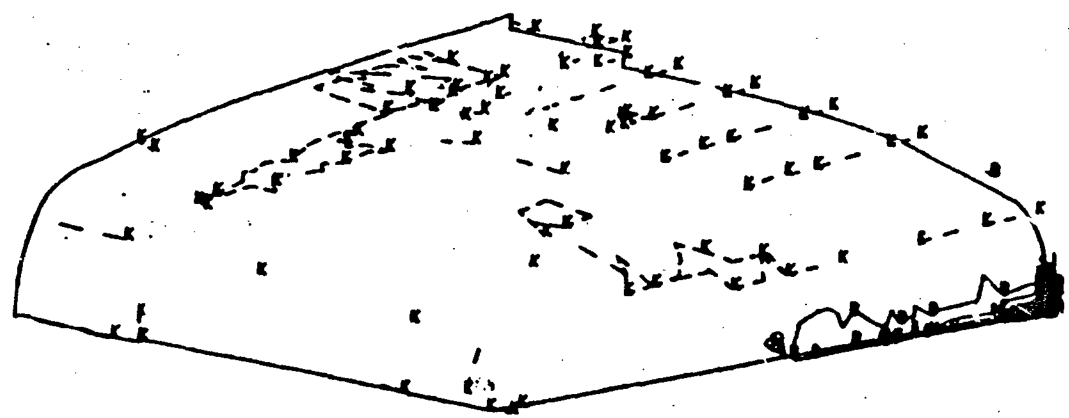


Figure 72. Shear Stresses (Sxy), Top Surface Of Truck Hood, Load Case B2



STRESS CONTOURS (p-i)

A = -1.416

B = 147.7

C = 296.9

D = 446.1

E = 595.3

F = 744.5

G = 893.7

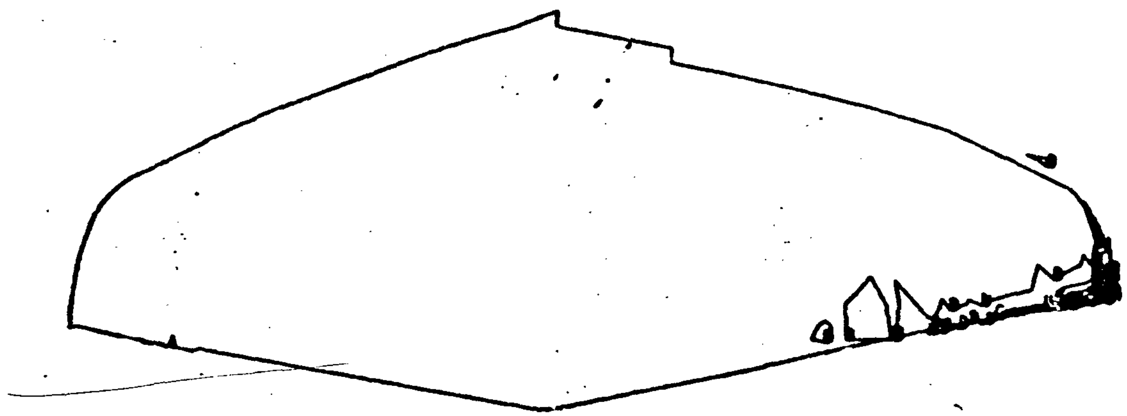
H = 1,042

I = 1,192

J = 1,341

K = 0.000

Figure 73. Maximum Principal Stresses (S_3), Top Surface of Truck Hood, Load Case B2



STRESS CONTOURS (psi)

A = 0.000
B = 124.4
C = 248.8
D = 373.2
E = 497.6
F = 622.0
G = 746.4
H = 870.6
I = 995.2
J = 1,119

Figure 74. Von Mises Equivalent Stresses (Seq), Top Surface Of Truck Hood, Load Case B2

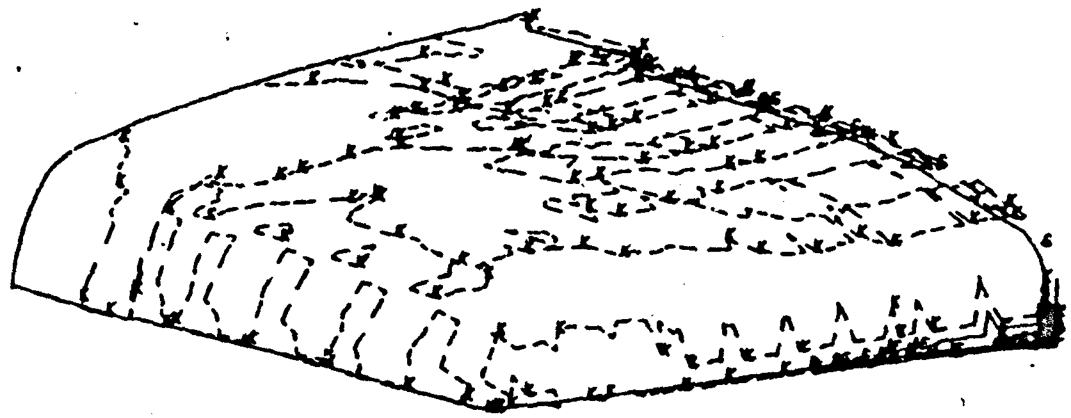


Figure 75. Transverse Stresses (Sxx), Bottom Surface Of Truck Hood, Load Case B2

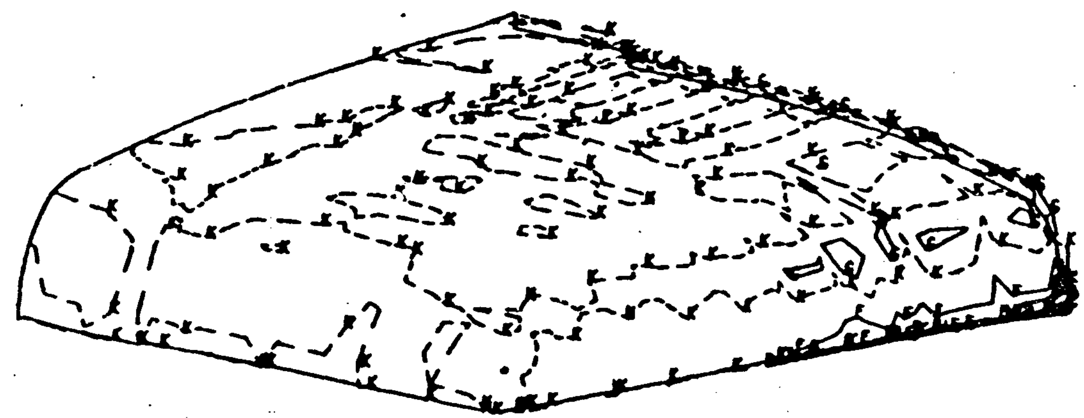
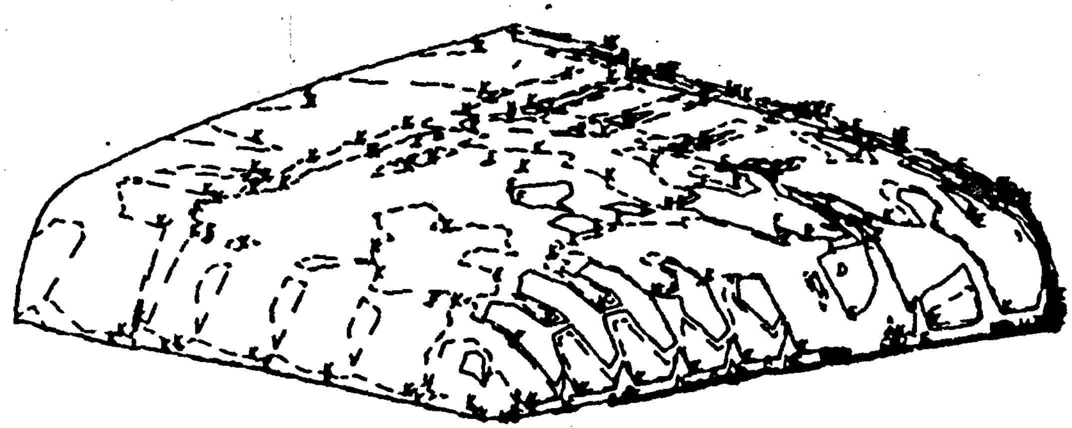


Figure 76. Longitudinal Stresses (Syy), Bottom Surface Of Truck Hood, Load Case B2



STRESS CONTOURS (psi)

A = -78.41

B = -62.29

C = -46.17

D = -30.05

E = -13.93

F = 2.185

G = 18.30

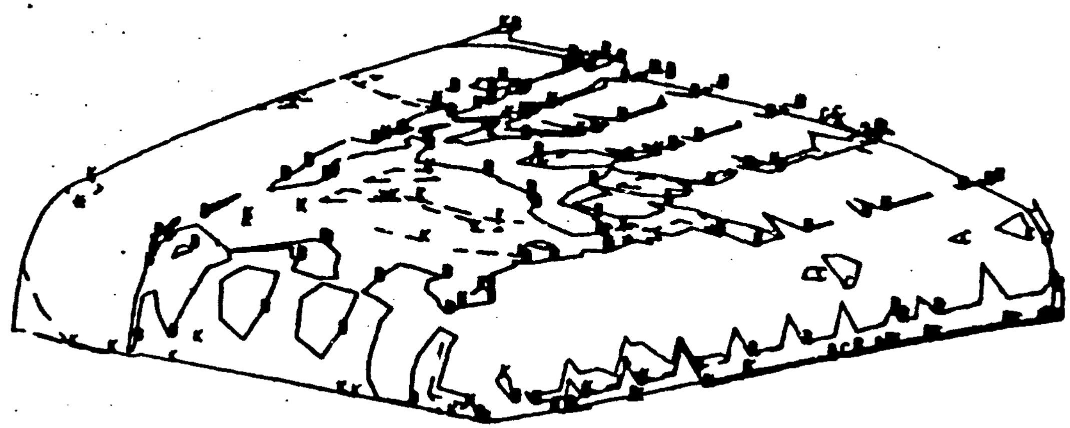
H = 34.42

I = 50.54

J = 66.66

K = 0.000

Figure 77. Shear Stresses (Sxy), Bottom Surface Of Truck Hood, Load Case B2



STRESS CONTOURS (psi)

A = 93.10

B = 1,357

C = 95.82

D = 190.2

E = 284.7

F = 379.2

G = 473.6

H = 568.1

I = 662.6

J = 757.0

K = 0.000

Figure 78. Maximum Principal Stresses (S_3), Bottom Surface Of Truck Hood. Load Case B2

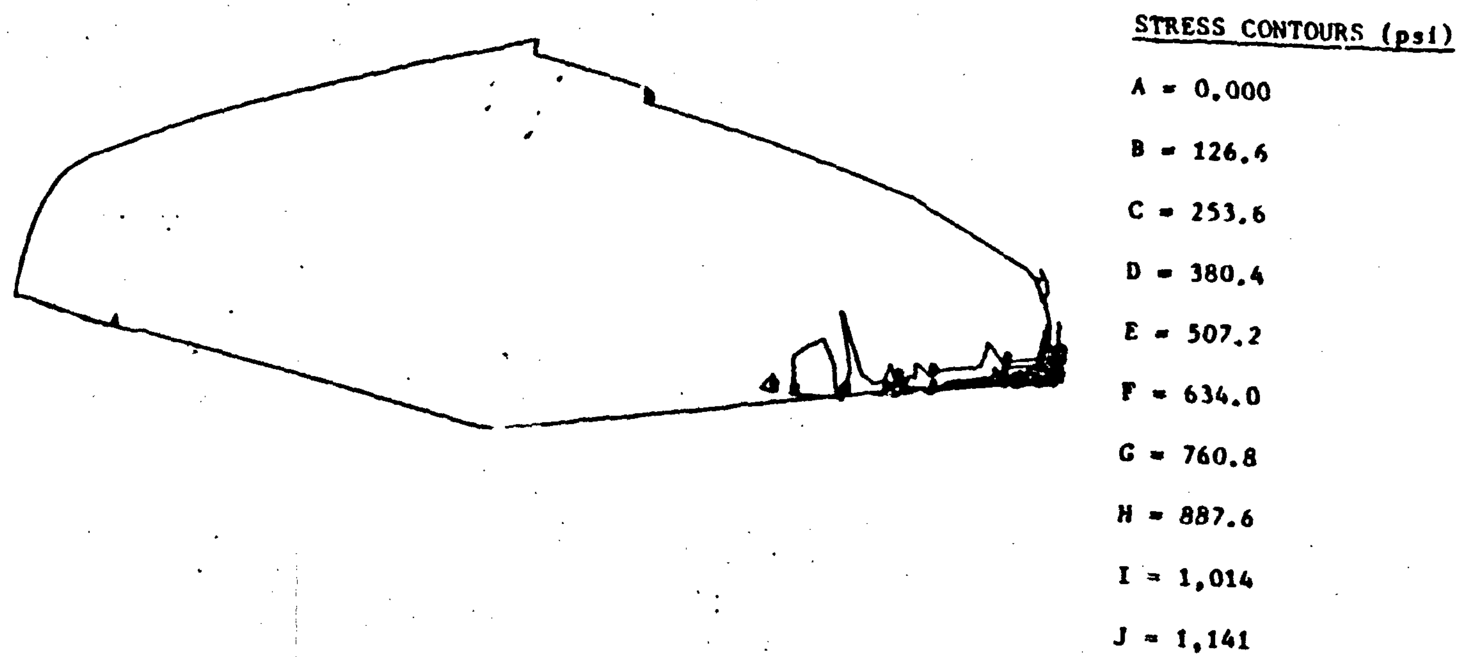
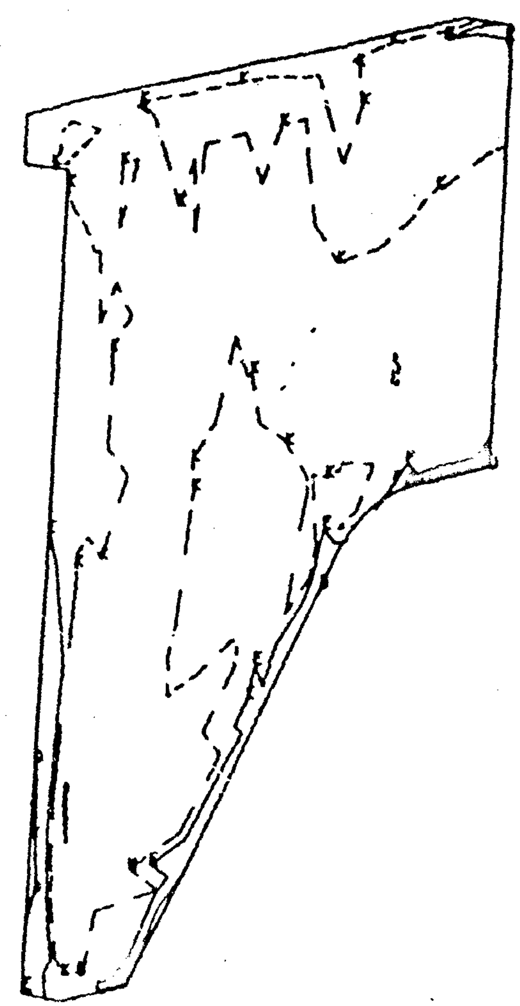


Figure 79. Von Mises Equivalent Stresses (Seq), Bottom Surface Of Hood, Load Case B2



STRESS CONTOURS (psi)

A = -3,844

B = -2,954

C = -2,064

D = -1,174

E = -284.1

F = 605.9

G = 1,496

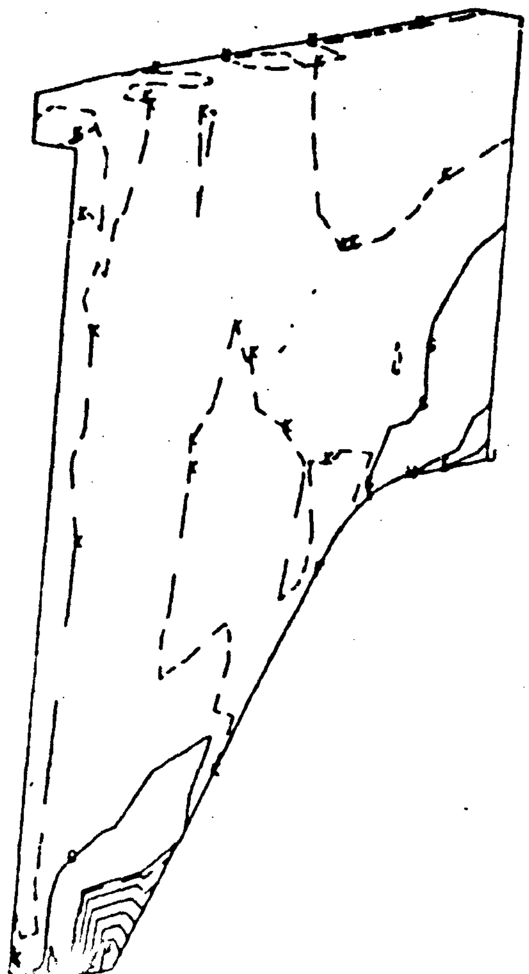
H = 2,386

I = 3,276

J = 4,166

K = 0.000

Figure 80. Transverse Stress Contours (Sxx), Of Side Panel, Top Surface, Load Case B2



STRESS CONTOURS (psi)

A = -2,733

B = -2,251

C = -1,769

D = -1,287

E = -804.6

F = -322.3

G = 159.9

H = 642.3

I = 1,124

J = 1,606

K = 0.000

Figure 51. Longitudinal Stress Contours (Syy), Of Side Panels, Top Surface, Load Case B2

B-2

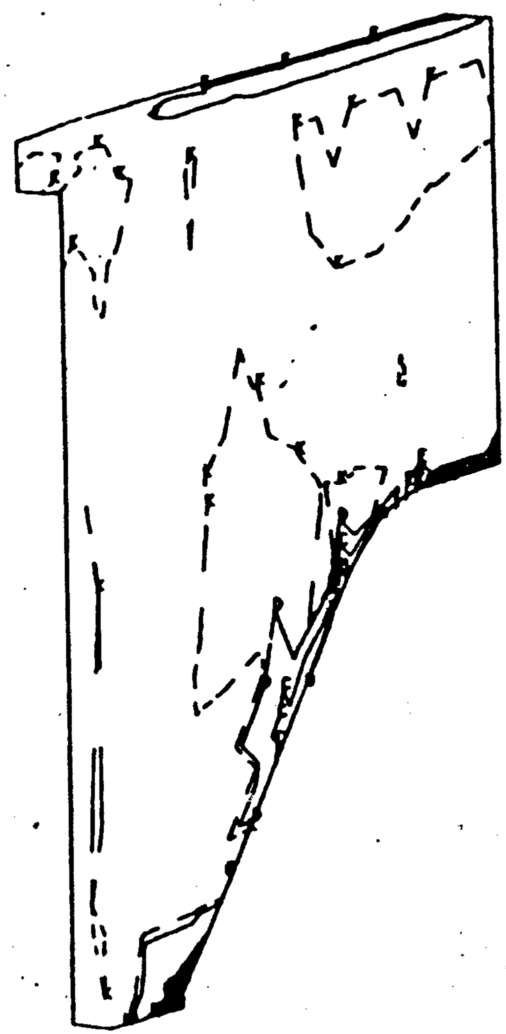


Figure 82. Shear Stress Contours (Sxy), Of Side Panels, Top Surface, Load Case B2

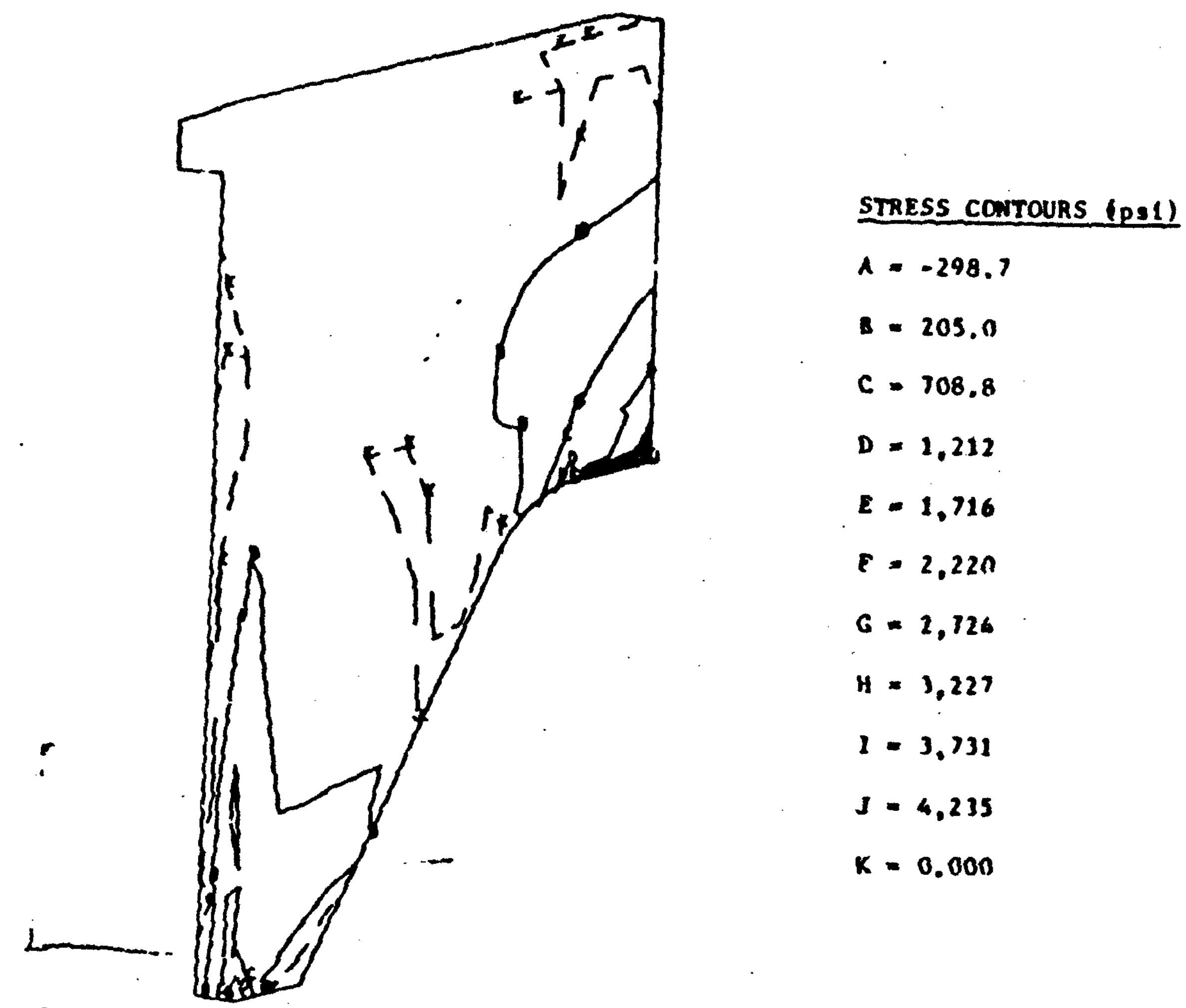


Figure 83. Maximum Principal Stresses (S_3), Of Side Panels, Top Surface, Load Case B2

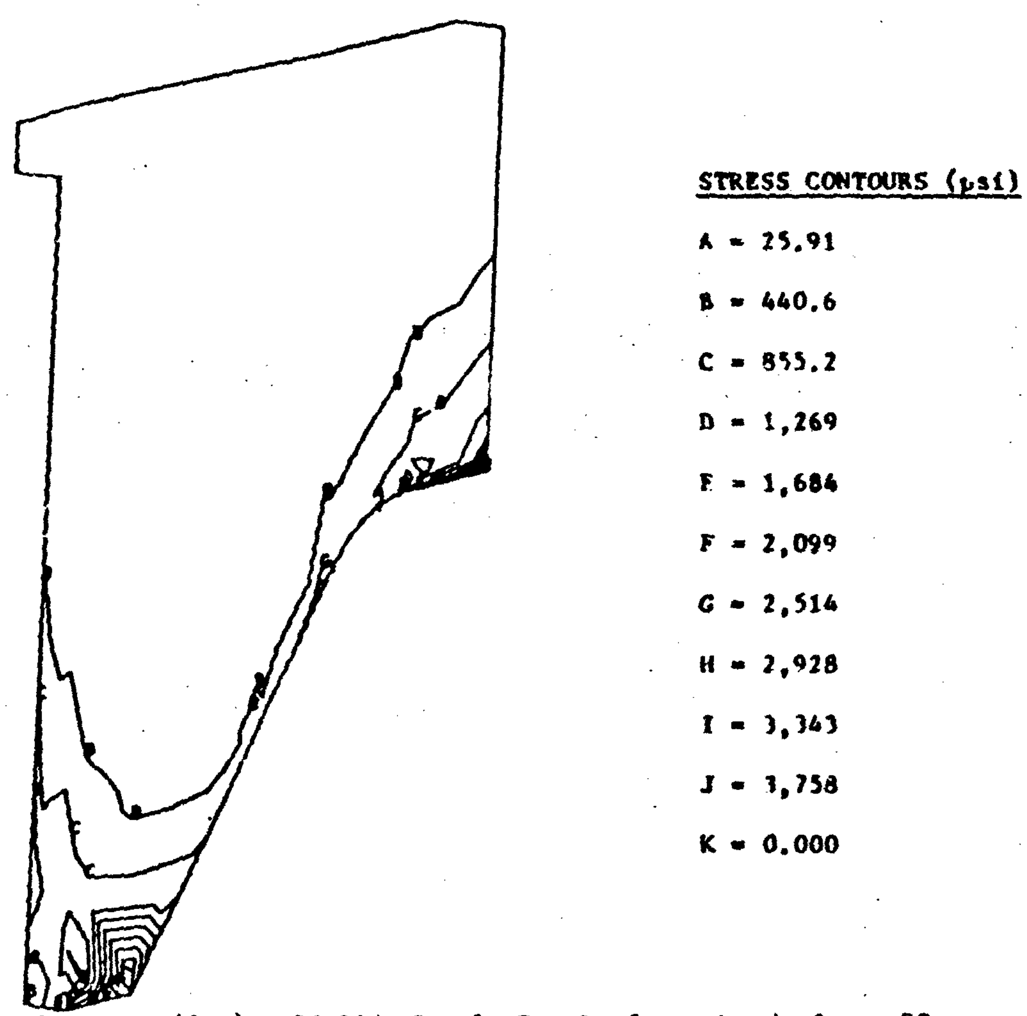


Figure 84. Von Mises Equivalent Stresses (Seq), Of Side Panel, Top Surface, Load Case B2

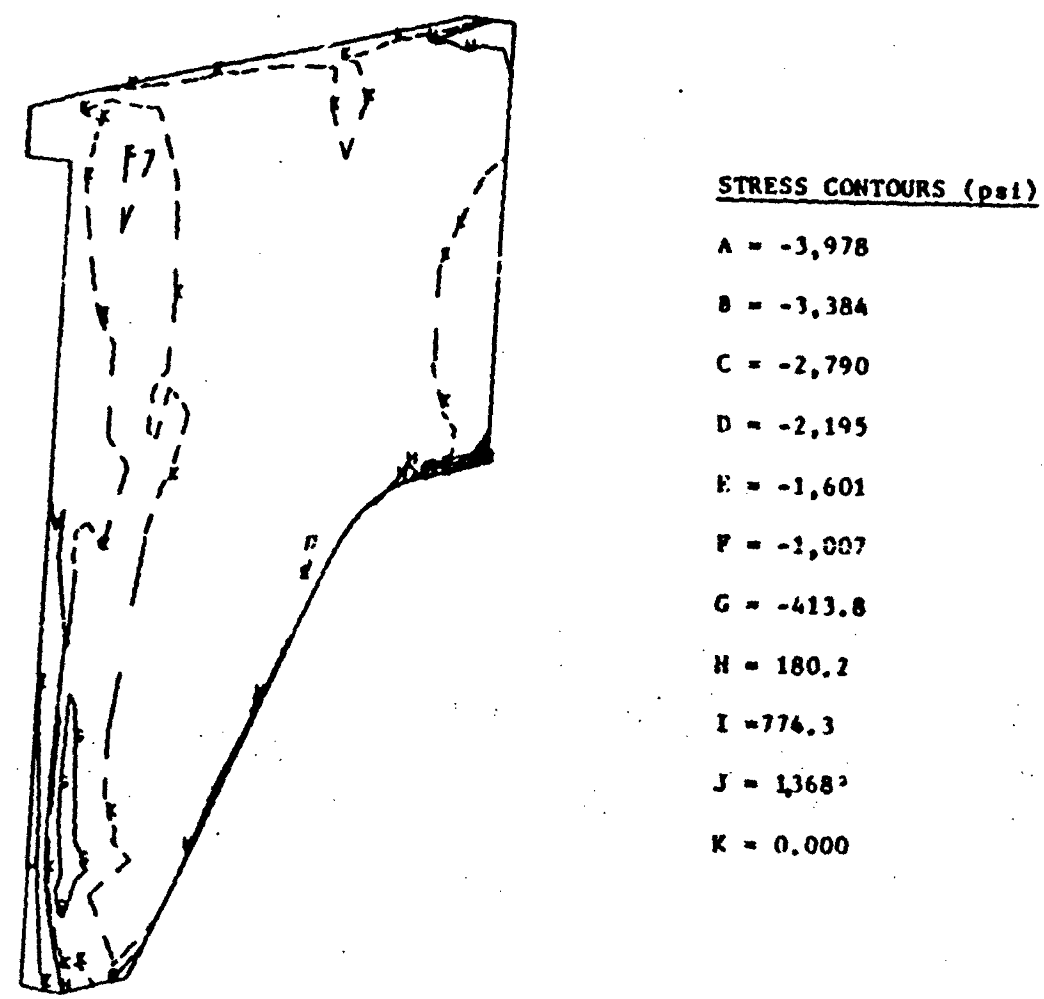
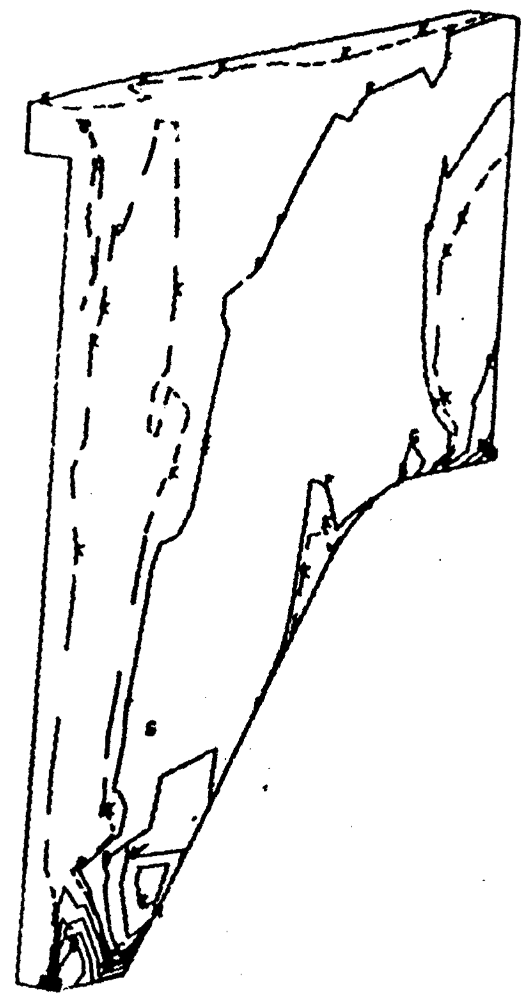


Figure B5. Transverse Stress Contours (Sxx), Of Side Panel, Bottom Surface, Load Case B2



STRESS CONTOURS (psi)

A = -1,245

B = -982.0

C = -718.6

D = -455.2

E = -191.8

F = 71.55

G = 334.9

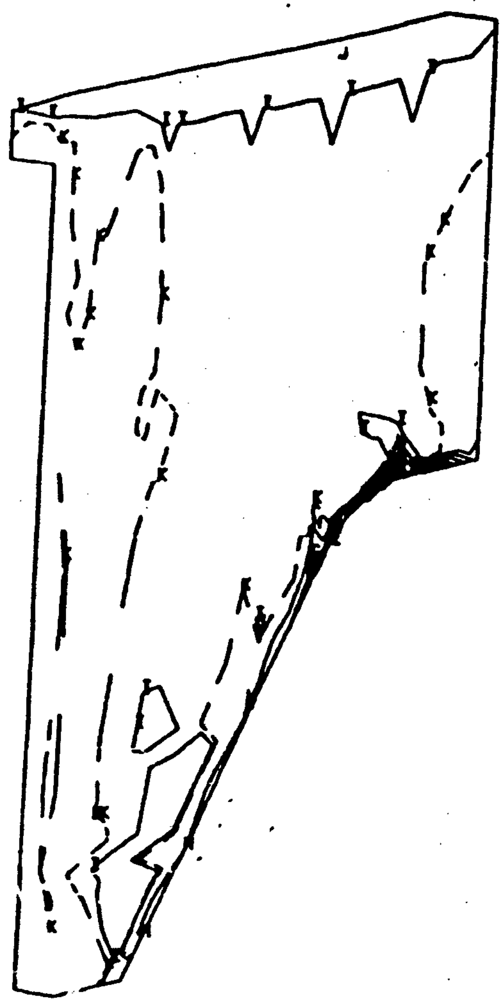
H = 598.3

I = 861.7

J = 1,125

K = 0.000

Figure 86 Longitudinal Stress Contours (Syy), Of Side Panels, Bottom Surface, Load Case B 2



STRESS CONTOURS (psi)

A = -664.5

B = -580.0

C = -495.6

D = -411.1

E = -326.7

F = -242.3

G = -157.8

H = -73.41

I = 11.03

J = 95.48

K = 0.000

Figure 87. Shear Stress Contours (Sxy), Of Side Panels, Bottom Surface, Load Case B2

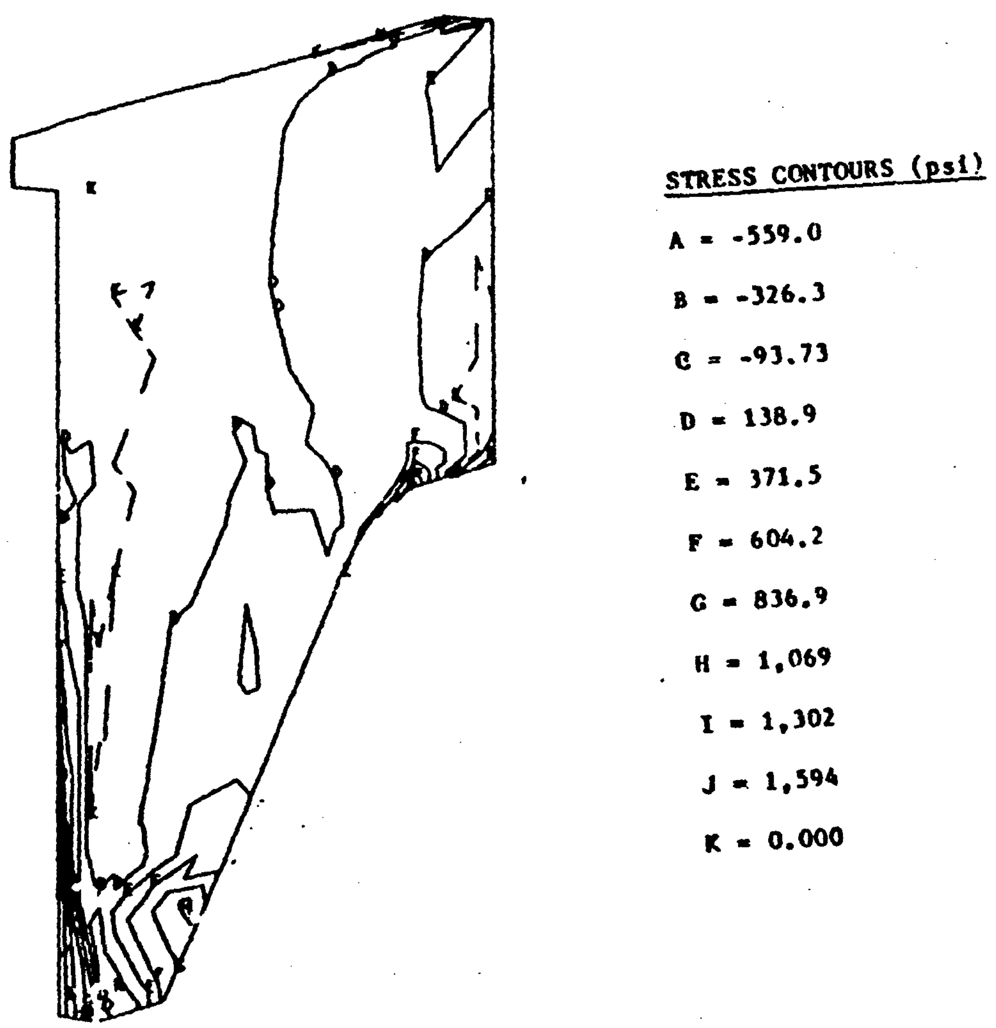


Figure 88. Maximum Principal Stresses (S_3), Of Side Panels, Bottom Surface, Load Case B2

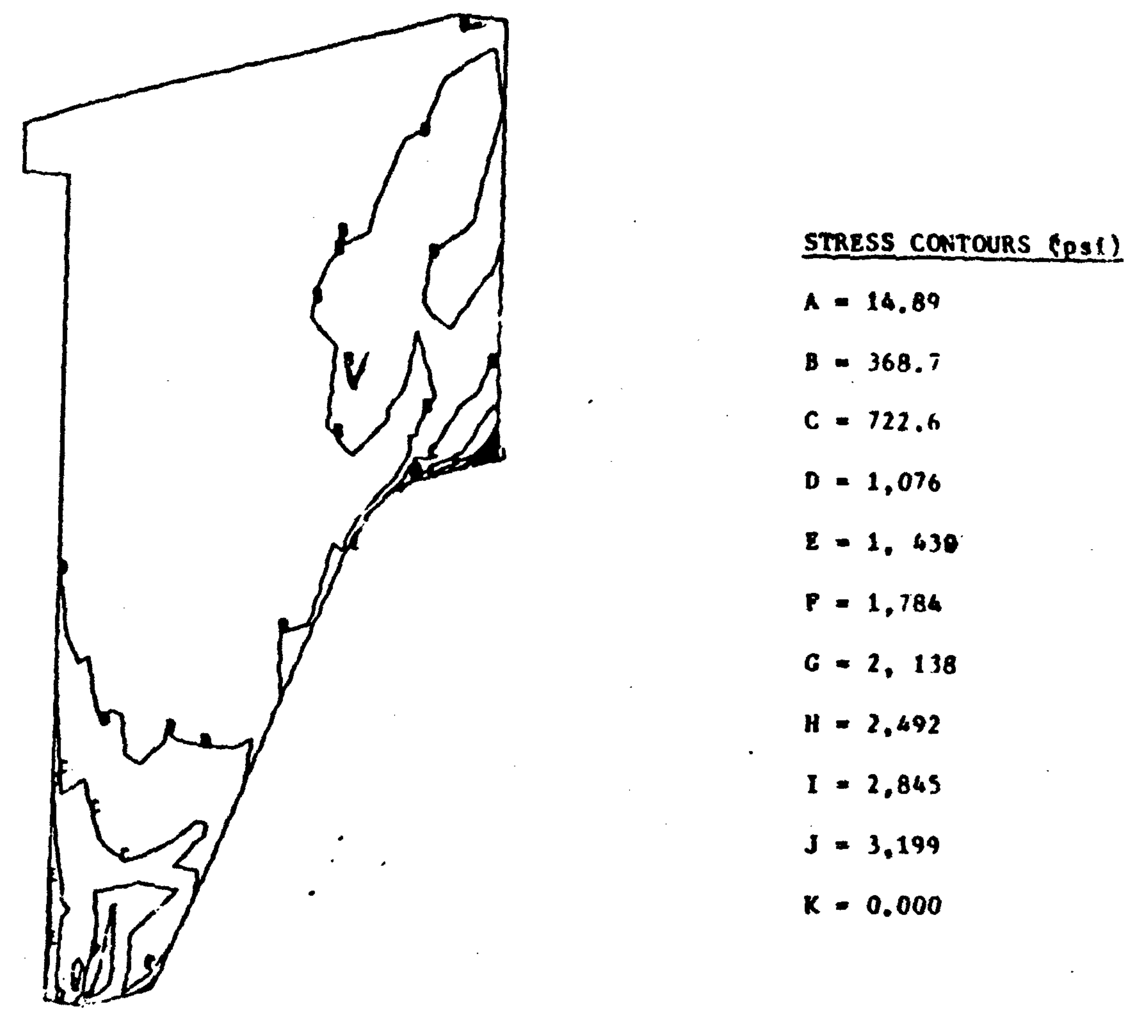


Figure 89. Von Mises Equivalent Stresses (Seq), Of Side Panels, Bottom Surface, Load Case B2

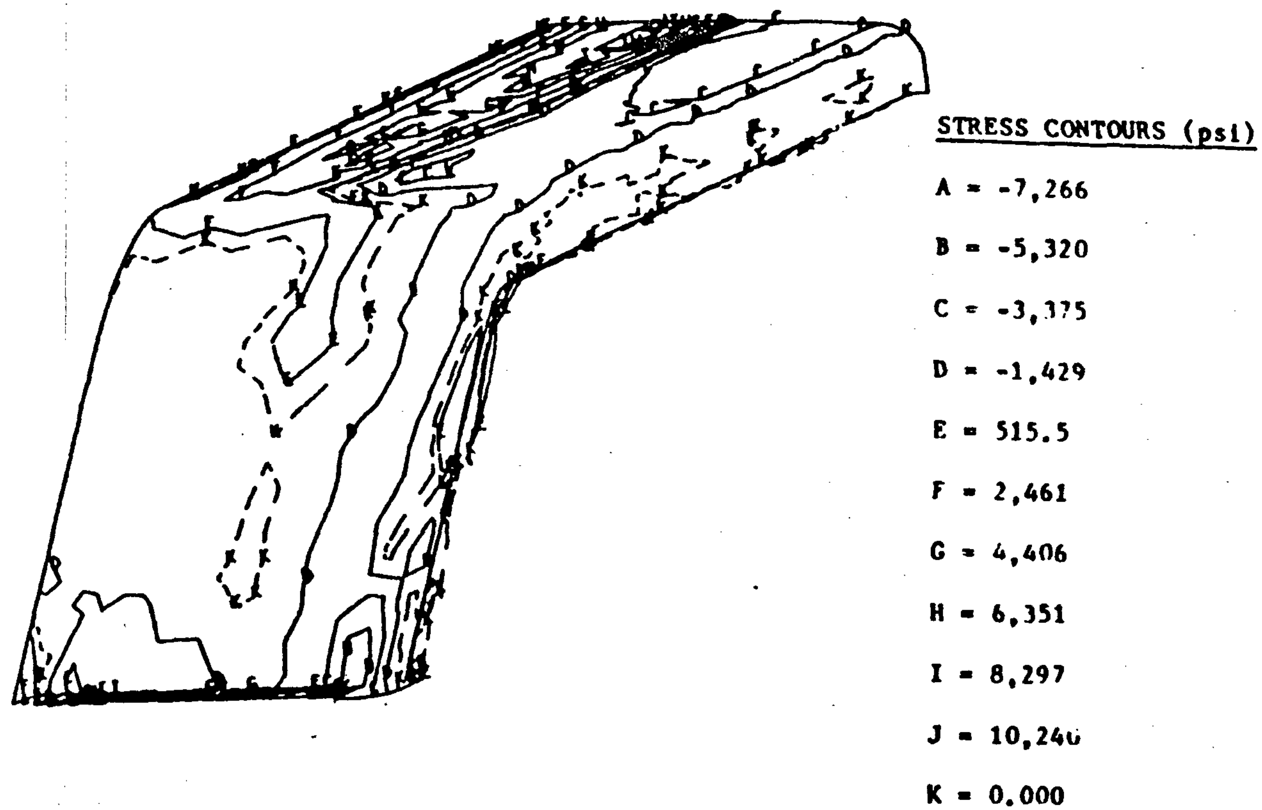


Figure 90. Transverse Stress Contours (Sxx), Of Side Fender, Top Surface, Load Case B2

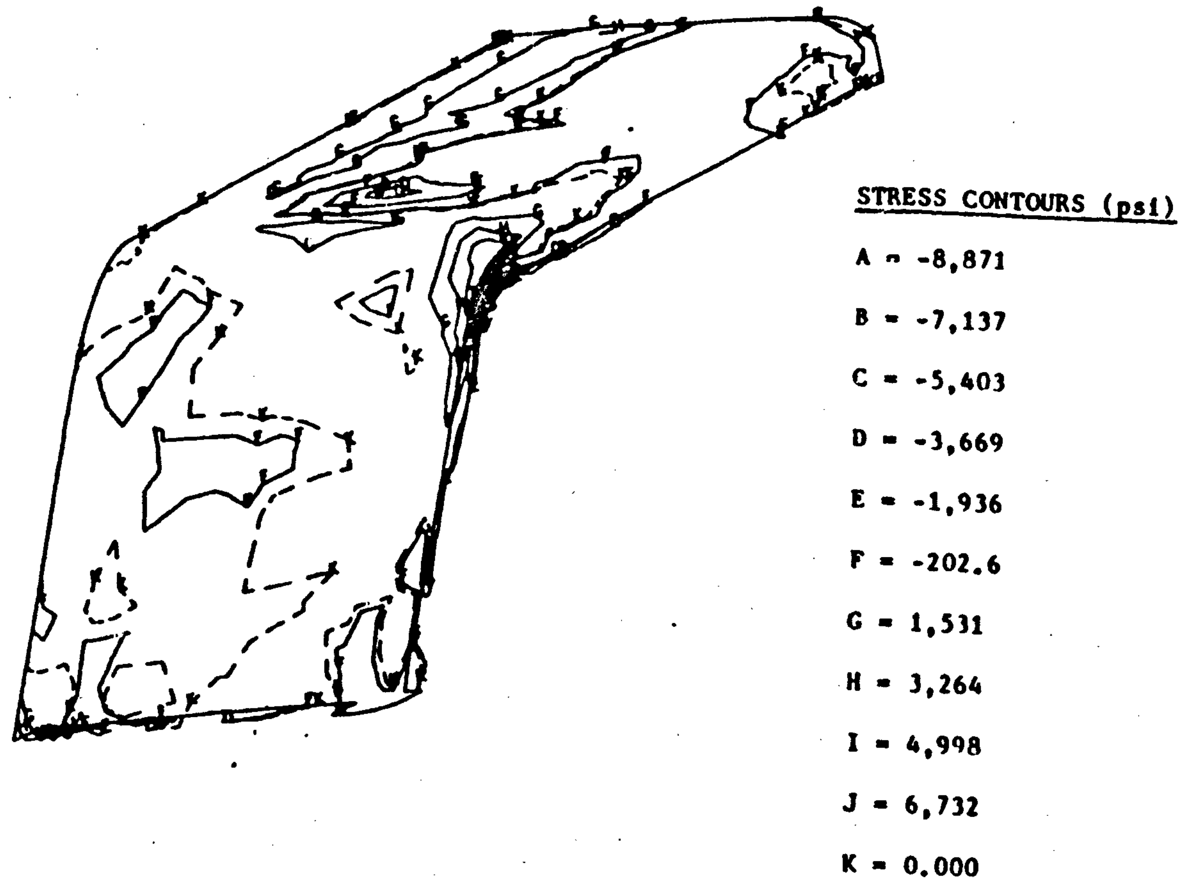
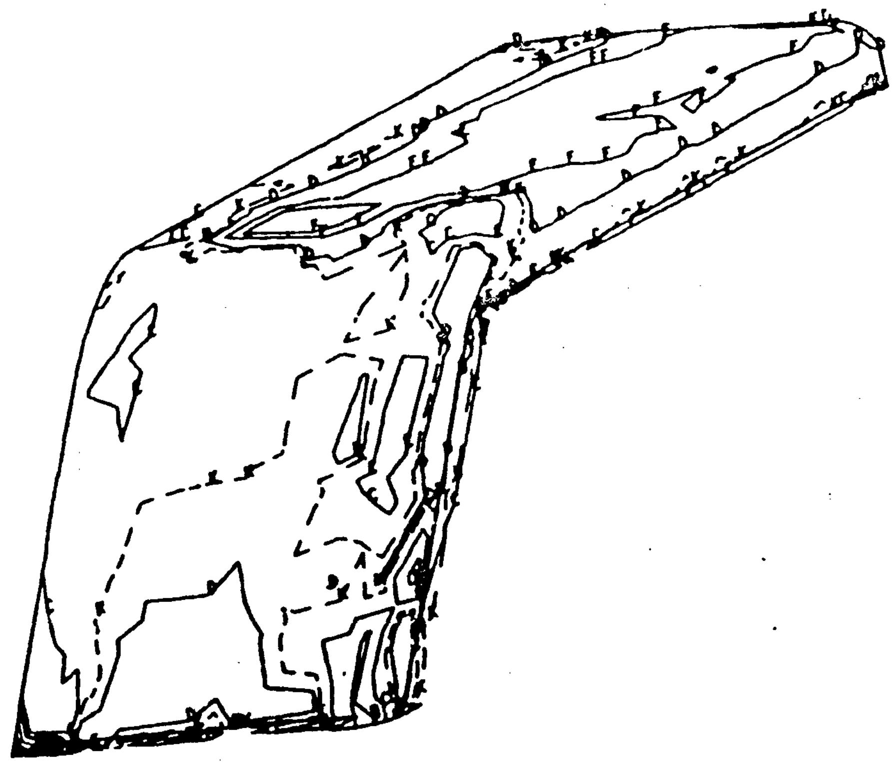


Figure 91. Longitudinal Stress Contours (Syy), Of Side Fender, Top Surface, Load Case



STRESS CONTOURS (psi)

A = -1,467

B = -922.0

C = -376.1

D = 169.7

E = 715.6

F = 1,261

G = 1,807

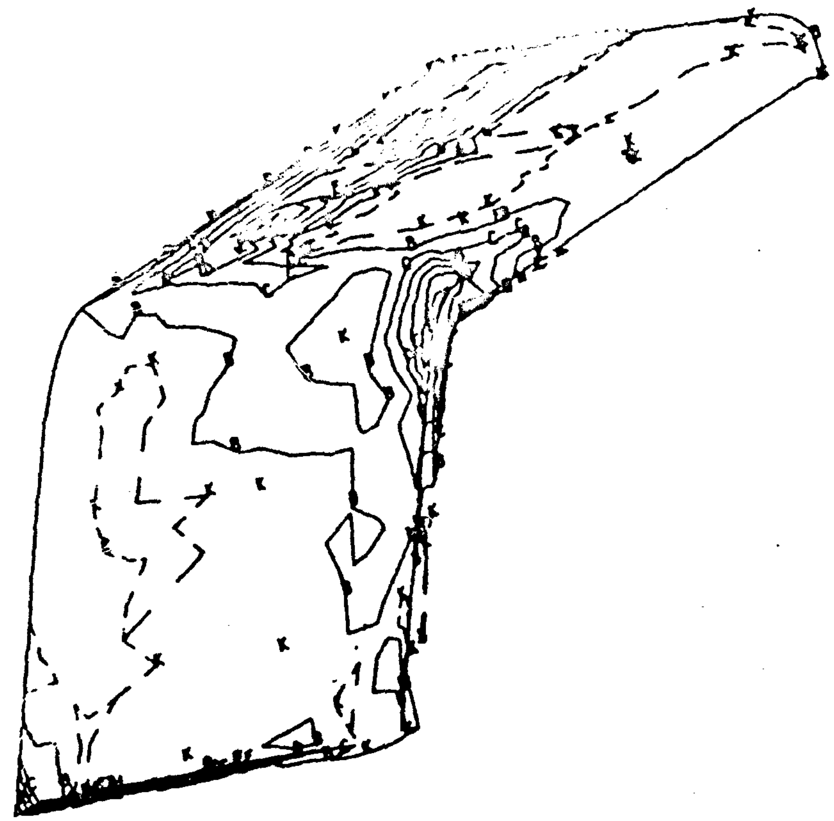
H = 2,353

I = 2,899

J = 3,445

K = 0.000

Figure 92. Shear Stress Contours (Sxy), Of Side Fender, Top Surface, Load Case B2



STRESS CONTOURS (psi)

A = -484

B = 710

C = 1,904

D = 3,098

E = 4,292

F = 5,486

G = 6,680

H = 7,874

I = 9,068

J = 10,260

K = 0.000

Figure 93. Maximum Principal Stress (S_3), Of Side Fender, Top Surface, Load Case B2

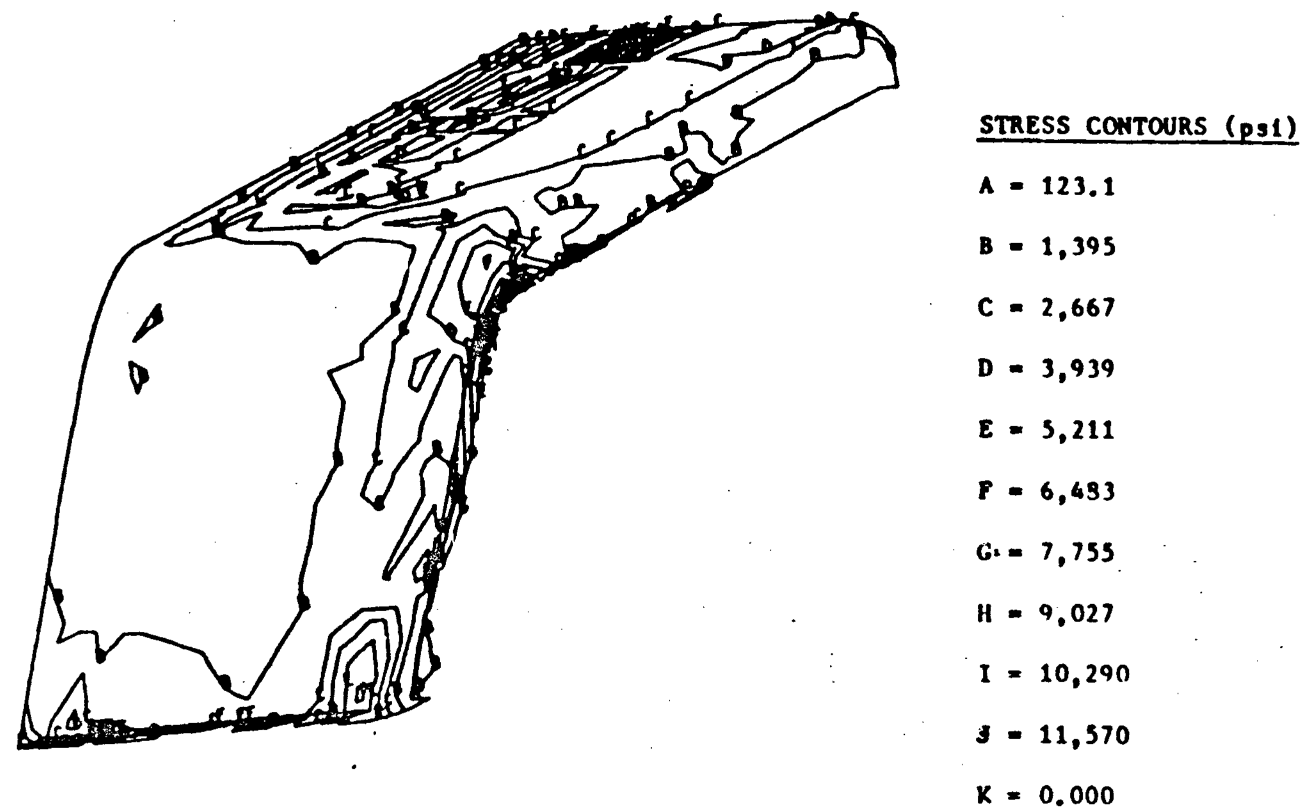


Figure 94. Von Mises equivalent stresses (Seq), of Side Fender Top Surface, Load Case B2

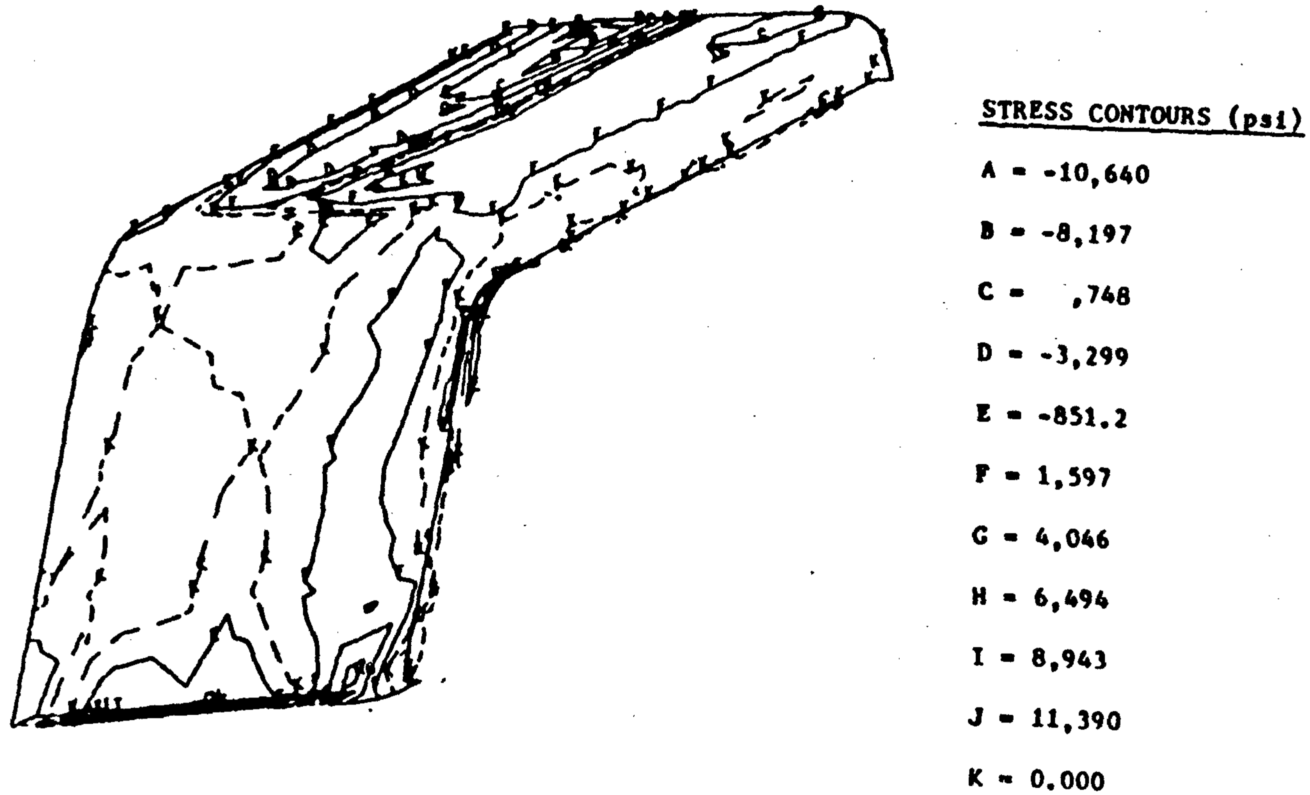
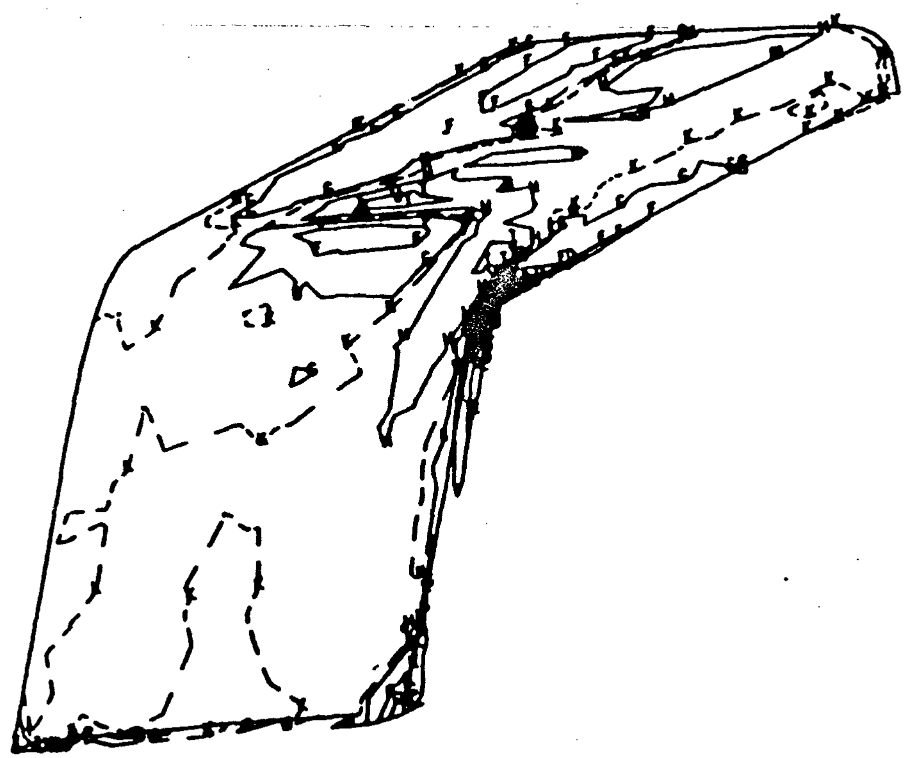


Figure 95. Transverse Stress Contours (Sxx), Of Side Fender, Bottom Surface, Load Case B2



STRESS CONTOURS (psi)

A = -9,870

B = -8,306

C = -6,742

D = -5,178

E = -3,614

F = -2,051

G = -487.1

H = 1,076

I = 1,64

J = 4,204

K = 0.000

Figure 96. Longitudinal Stress Contours (Syy), Of Side Fenders, Bottom Surface, Load Case B2

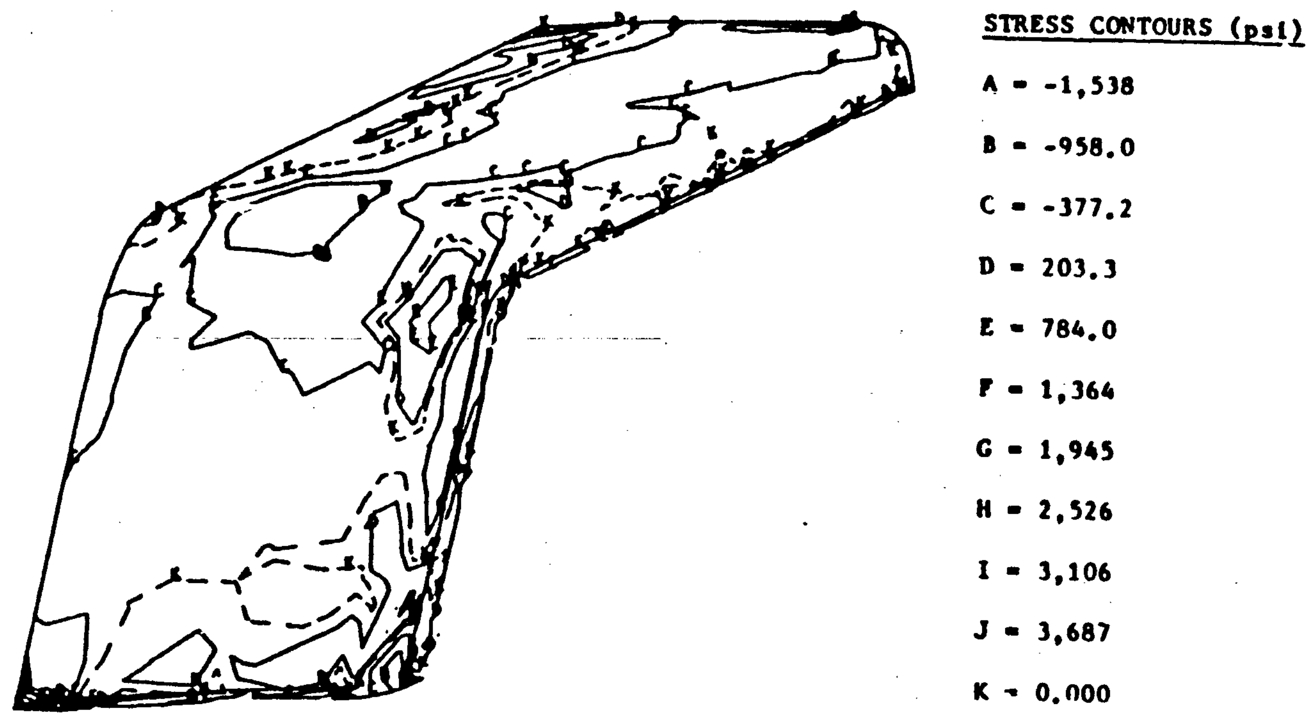


Figure 97. Shear Stress Contours (Sxy), Of Side Fender, Bottom Surface, Load Case B2

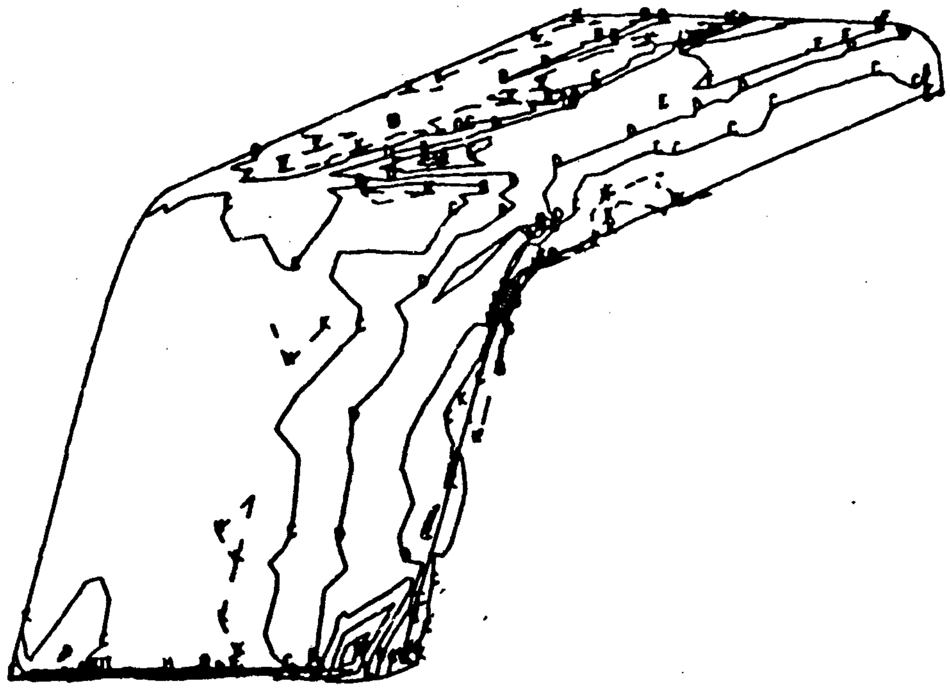


Figure 98. Maximum Principal Stress (S_3), Of Side Fender, Bottom Surface, Load Case B2

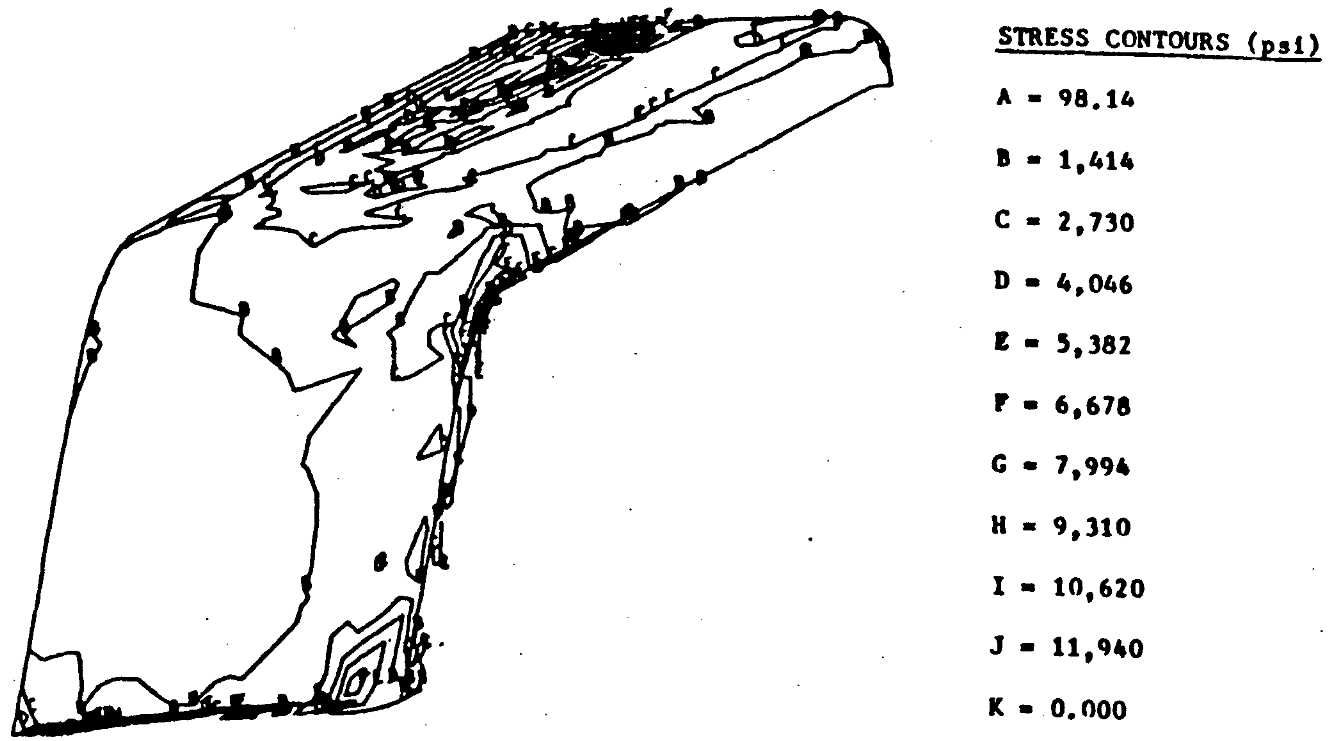


Figure 99. Von Mises Equivalent Stresses (Seq), Of Side Fender, Bottom Surface, Load Case B2

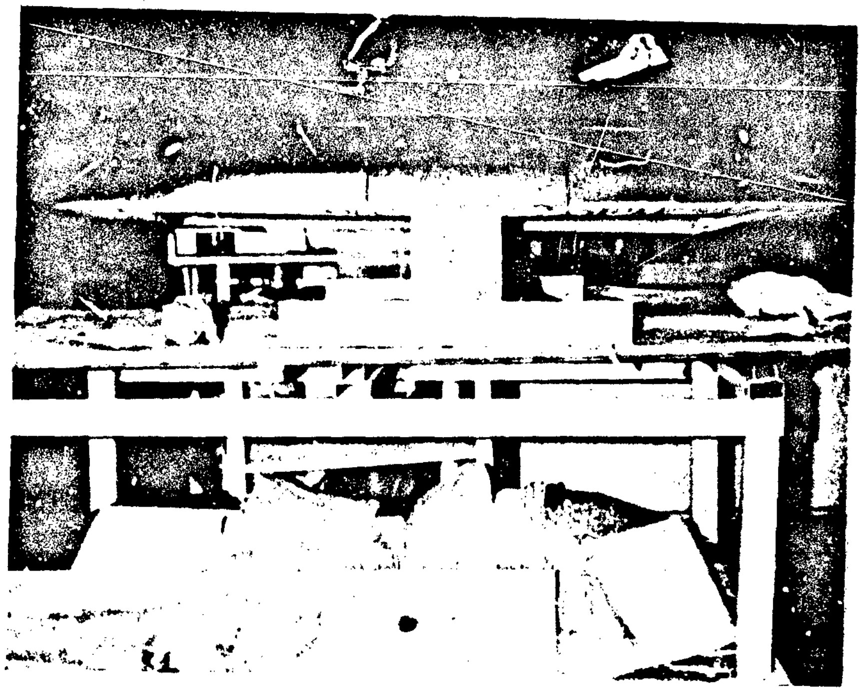
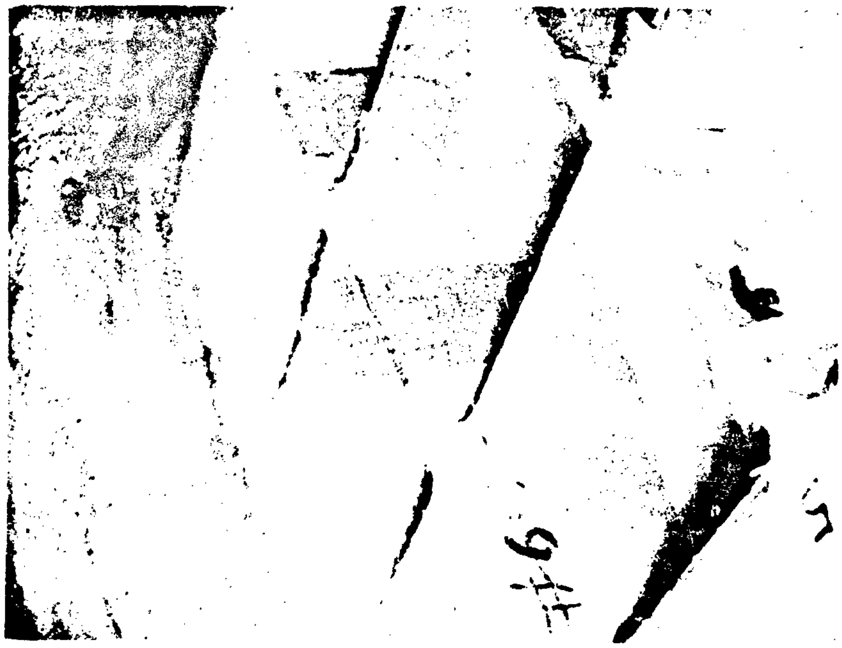


Figure 100. Hood With Internal Build-Up

Figure 101. Hood With External Build-Up Ready For Application Of The Plastic Tooling

Figure 102. Crating To Provide Support Per Plastic Tooling



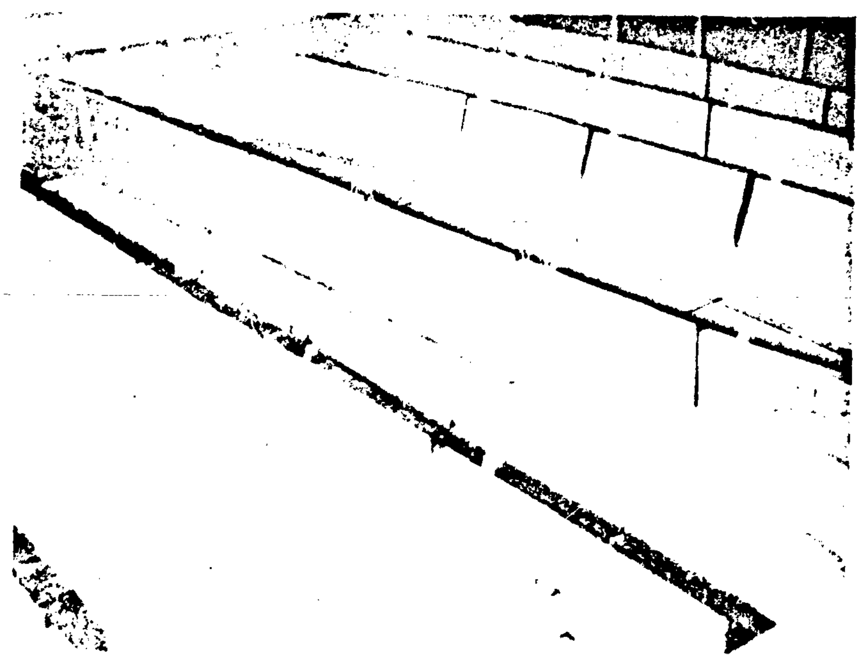


Figure 103. Close-Up Of Crating

Figure 104. Surface Coating Of Actual Component

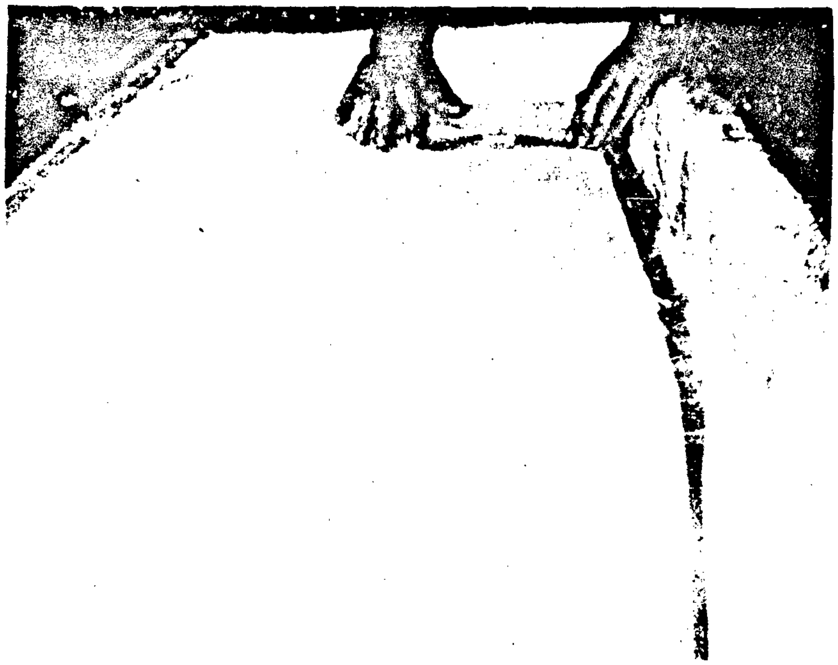


Figure 105. Application And Lamination Of Fiberglass And High Temperature Epoxy R'sin

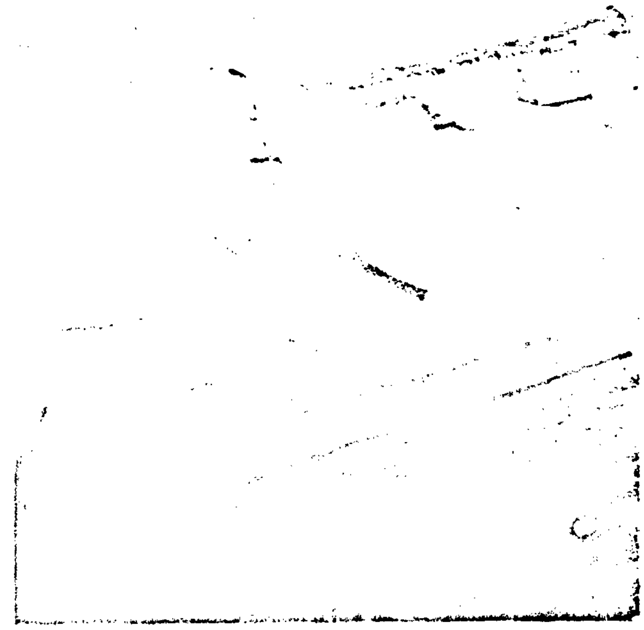


Figure 106. Application Of Felt Tape Around Component Contour Lines To Transfer Intricate Surfaces Fom Steel Part To The Composite Tool

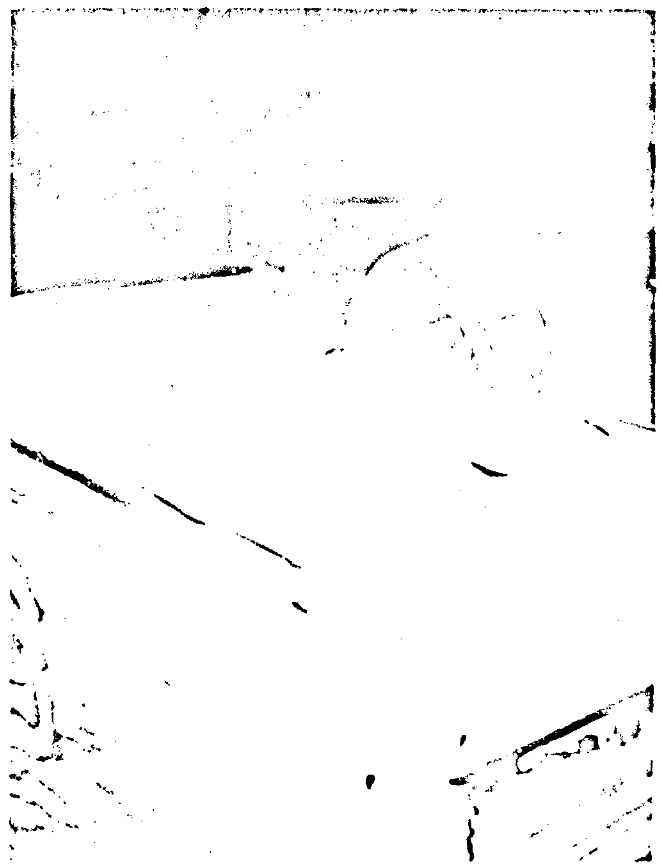


Figure 107. Application Of Bagging In Order In Order To Apply Vacuum

Figure 108. Composite Tool Under Vacuum

Figure 109. Composite Tool During Curing

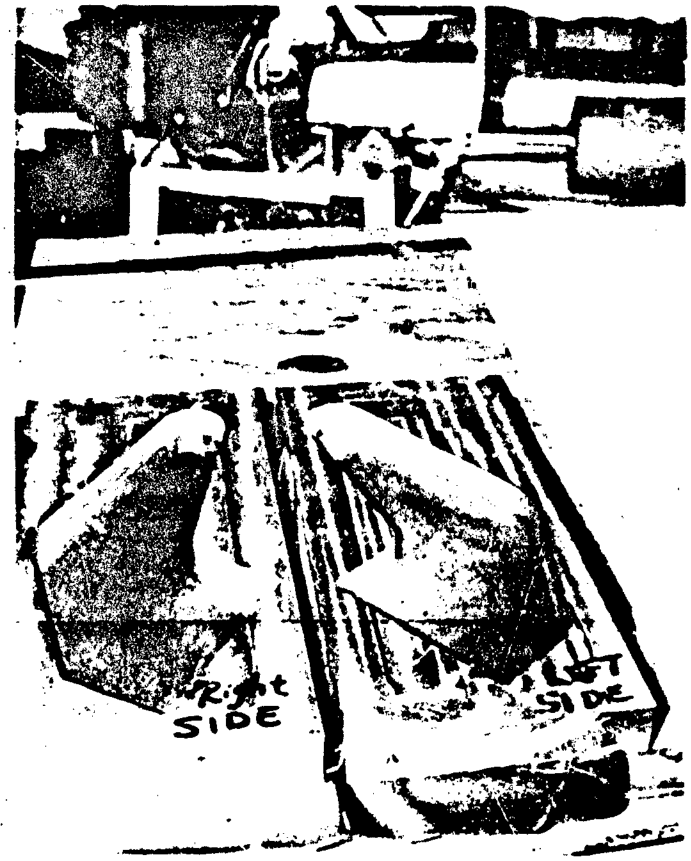


Figure 110. Aluminum Tooling For The Grille Opening Panels

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